

AB
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S250C HF/VHF SIMULATOR

USER'S MANUAL

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SECTION 1
OVERVIEW**1.0 INTRODUCTION**

The Signatron Model S250C HF/VHF Channel Simulator is the fourth generation of the Signatron HF/VHF simulation product line. It provides a means of testing frequency hopping and non-hopping HF and VHF modems and radios. Fully computer controlled, the S250C implements a software-based real-time simulation of an extended Watterson channel model over the entire 2-90 MHz HF/VHF band, including both groundwave and skywave components. It also simulates multipath due to terrain and building reflections on VHF links.

The S250C provides both baseband and frequency hopping RF interfaces to the equipment under test, thus permitting a modem to be tested as a stand-alone unit, without a terminal, as well as integrated with a terminal. The simulator can be used to test half-duplex modems and radios, with up to six multipath components in each direction. Each path is characterized by: a signal amplitude, delay, Doppler spread, Doppler shift and, a Gaussian noise amplitude. In addition, the simulator supports additive impulse noise, jamming, and intermodulation interference effects. In the non-hopping mode, the simulator supports dual diversity frequency channel simulation. Tables 1.1 and 1.2 contain the simulator specifications. Figure 1.1 shows a block diagram of the simulator and its radio and modem interfaces.

1.1 APPLICATIONS

Figures 1.2a and 1.2b depict typical uses for the S250C simulator. These figures show how the simulator provides an artificial HF/VHF channel for testing modems and related communication equipment. The artificial channel is fully reproducible, meaning different radios can be tested and compared with identical simulator HF/VHF channel and noise conditions. A commercially available Bit Error Rate Test Set may be used to monitor system performance.

Table 1.1 Interface Specifications S250C HF/VHF Channel Simulator

RF

Input/Output Frequency	HF/VHF 2 - 90 MHz
Signal Bandwidth:	80 kHz
Input/Output Impedance	50 Ω
Input/Output VSWR	<1.5:1
Input Signal Level:	+30 to -10 dBm
Output Signal Level:	-10 to -110 dBm
Output Spurious Levels:	Min. 50 dB below signal level
Group Delay:	Constant to within 5 μ Sec

Baseband

Input/Output Frequency:	300 Hertz to 20 kHz
Signal Bandwidth:	20 kHz
Input/Output Impedance	600 Ω , balanced
Input Signal Level	0 dBm to -10 dBm, RMS
Output Signal Level	0 dBm to -40 dBm
Output Spurious Levels:	Min. 50 dB below signal level
Group Delay:	Constant to within 5 μ Sec

Frequency Hop Control

Frequency Hopping	
Number of Channels:	1 to 128
Hop Rate:	0 to 1000 hops/sec
Simulation Modes:	Non-frequency hopping or frequency hopping
Frequency Hop Interface:	Radio-specific

Table 1.2 S250C HF/VHF Channel Simulator Capability Specifications

Number of Paths:	6 (5 for mode with fading jammer)
Number of Diversities:	2 (maximum 6 paths total)
Path Amplitude:	0 to -40 dBm, plus OFF
Path Statistics:	Complex Gaussian (skywave) or non-fading (groundwave)
Doppler Spread per Path:	0, and 0.05 to 10 Hz RMS (2s)
Doppler Shift per Path:	-1000 Hz to +1000 Hz
Delay:	Minimum 6 msec
of Earliest Path:	0 to 100 msec (non-hopping)
of Other Paths, relative to First Path:	-10 to 100 msec (frequency-hopping)
Delay Resolution:	10 μ Sec
Additive Gaussian Noise:	-3 to -40 dBm, plus OFF (frequency and location dependent)
Additive Impulse Noise:	+12 to -40 dBm, plus OFF
Level	Periodic or Random
Modes:	0.002 to 5,000
Impulses per Minute:	10 μ Sec to 1.0 second in multiples of 10 μ Sec
Impulse Duration:	
In-band Jamming	
Level:	0 to -100 dBm, plus OFF
Types:	One or two CW tones, Linear (swept) FM, Sinusoidal FM, FM Noise, Impulse

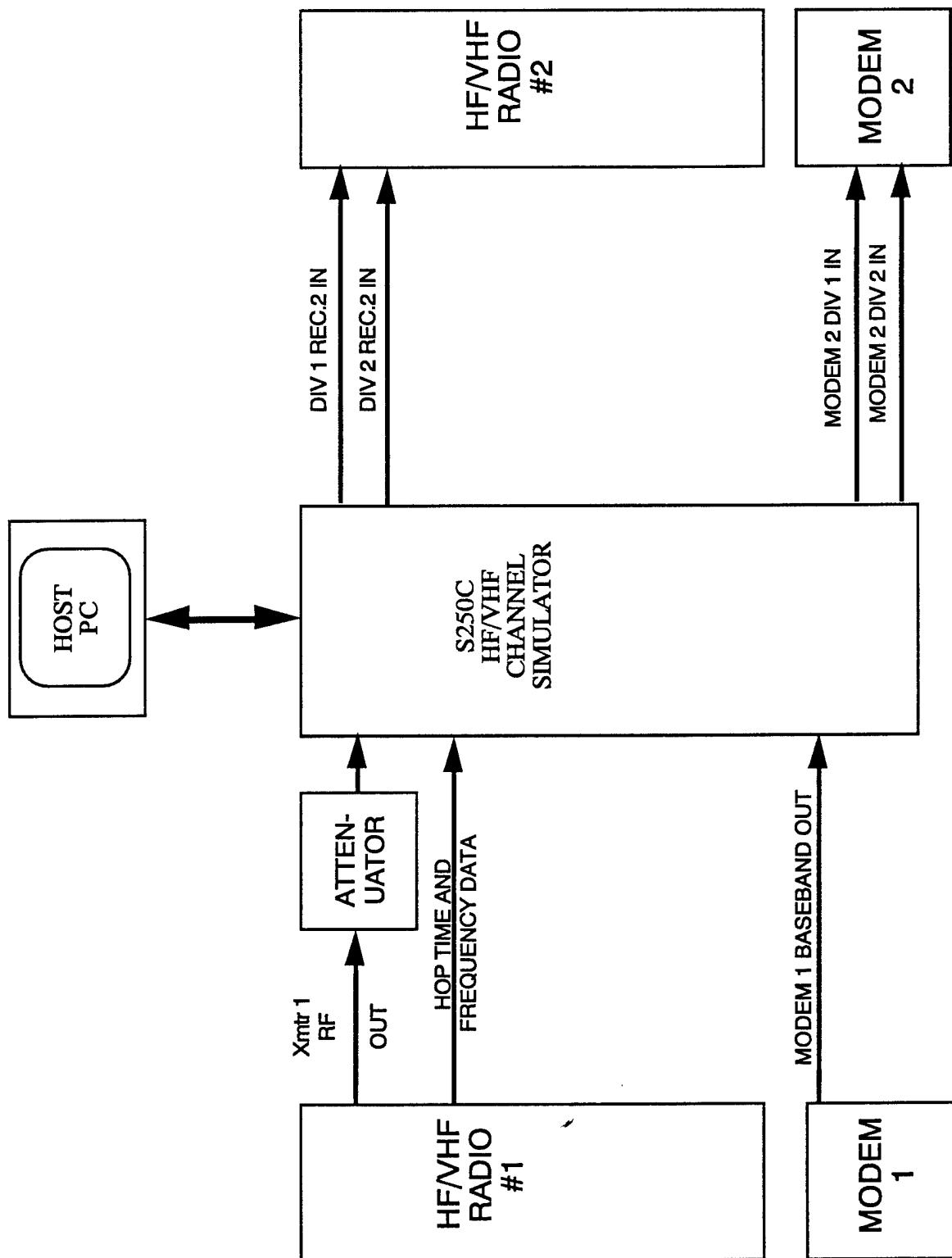


Figure 1.1 Simulator Interfaces

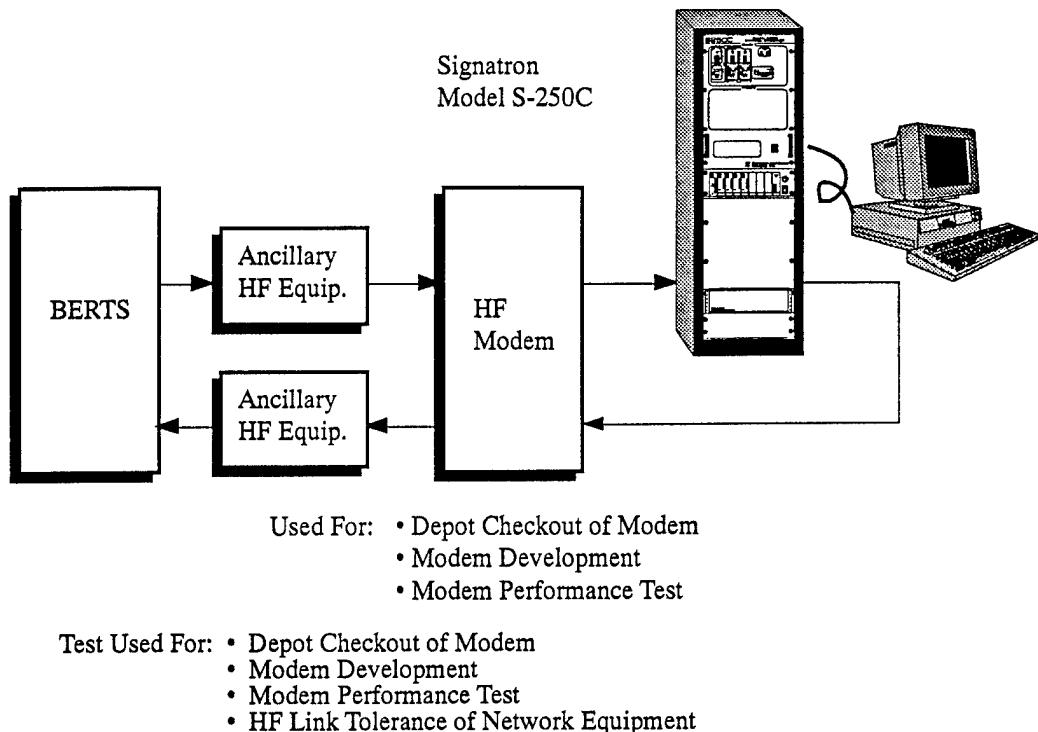


Figure 1.2a Loop Back Modem Test

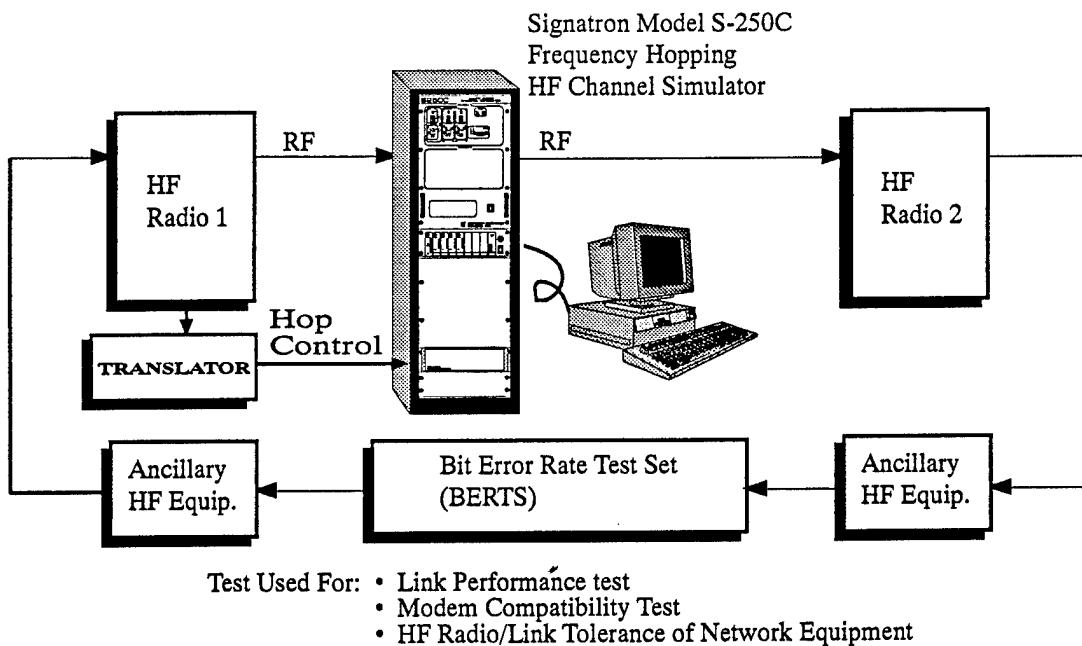


Figure 1.2b One-Way Radio Transmission Test

1.2 NEW FEATURES OF MODEL S250C

The Model S250C uses the latest signal processing technology to offer enhanced simulation capability. A major departure from previous models (S250A and S250B) is the digital hardware implementation of the tapped delay model of the HF channel. By not using a programmable processor for these functions, we have achieved two things:

- *Improved Capabilities.* Increased bandwidth and larger delays are possible.
- *Improved Portability and Maintainability.* Software can now run as compiled in the C language, without recoding in assembly language.

The enhancements include:

- Channel bandwidth tripled, up to 80 kHz RF or 20 kHz baseband.
- Minimum simulator group delay reduced to 6 msec, allowing realistic path delays in simulations.
- Maximum path delay increased to 100 msec.
- Delay resolution quadrupled, to 10 μ sec (100 kHz sample rate).
- Automatic Gain Control on the input compensating for transmitter level variation during simulations.
- Dual diversity in both non-hopping and hopping modes. Previously models were restricted to one diversity when frequency hopping due to signal processing constraints.
- Impulse noise is now broadband at all pulse durations. In previous simulators the bandwidth of the impulse was inversely proportional to the duration. Also, a new impulse can occur at any time, whereas with previous models buffer constraints limited the simulation to no more than one impulse in 256 samples.

The Model S250C is fully upgradable to realistic two-way link simulation.

1.3 CHANNEL SPECIFICATION

The S250C uses a hardware tapped delay line channel model of the radio channel, the same model as used by Watterson to model the HF channel. Since the channel tap weights are implemented in software, the various types of paths at a given frequency (skywave, groundwave, and line-of-sight) are modeled by properly specifying the tap amplitudes, delays, Doppler Shifts, and Doppler spreads. As shown in Figure 1.3, all of these frequency channel parameters for a given simulation are contained in "parameter" files which are created, beforehand, either directly using GENPAR (v.1.3), the parameter file generator software package, or from radio link data using HFPRED (v.1.3), SIGNATRON's HF Channel Prediction software package.

Each parameter file contains path characteristics (for up to 128 different frequencies) and interference specifications. These files are read by the simulator, stored in its memory, and used during its real-time execution. In addition to creating parameter files, GENPAR allows the user to create "master" files. A master file is a file which contains a list of parameter file names. Given the name of a master file, the simulator then is able to model many different channels in succession. This becomes useful when running a series of tests on a radio or modem. Section 2 describes how to use the GENPAR program.

HFPRED is a software package which automates the process of setting the path parameters. It allows groundwave and skywave predictions to be made for overwater as well as overland paths. For overwater paths, the groundwave prediction is independent of sea state as only the strength of the groundwave is predicted. However, the user can adjust the strength of the groundwave (using GENPAR) to account for additional attenuation due to different sea states. The operator inputs the relevant link parameters -- latitude, longitude, time of day, sunspot number, locale, transmitter power, etc. -- to the program, and it computes the propagation parameters as a function of frequency and writes them into a parameter file. If this parameter file is then read using GENPAR and saved with the signal levels normalized (described in Section 2) it may then be used as an input to the simulator. Section 4 details the operation of HFPRED.

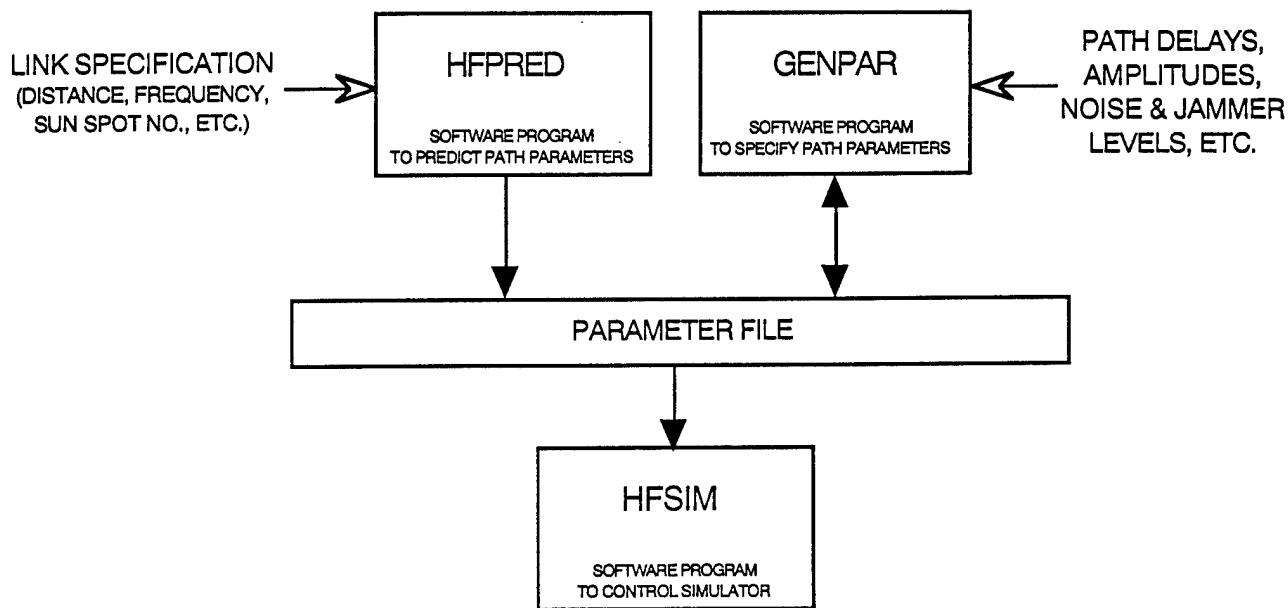


Figure 1.3 Software Organization

1.4 CHANNEL MODELS

There are two types of channel models incorporated into the S250C HF/VHF channel simulator: the non-frequency hopping model, based on an extension of Watterson's narrowband HF channel model and the frequency hopping model, which is based on a modification of the Watterson model.

The following section discusses the design basis of both models.

Non-Hopping HF Channel Model:

Watterson, et al* have provided experimental confirmation of an HF channel model that is amenable to real-time software simulation. This basic model, coupled with modifications allowing changeable filter bandwidths and frequency hopping effects, is incorporated into SIGNATRON's family of S250 HF channel simulators.

* Clark C. Watterson, John R. Juroshek and William D. Bensems, "Experimental Confirmation of an HF Channel Model", IEEE Transactions on Communication Technology, December, 1970, pp. 792-803.

For the non-frequency hopping channel, the Watterson model represents the channel as an ideal tapped-delay line with adjustable tap spacing having a complex gain multiplier for each tap, and a summation elements which combines the delayed and weighted signal components. (See Figure 1.4a.) The transmitted (baseband) signal feeds the tapped delay line. Tap spacings are selected to match the relative propagation delay of each resolvable multipath component (or path) within the channel. The tap gains of each path are random processes having the following constraints:

- 1) Each tap gain's real and imaginary components are Gaussian, producing Rayleigh fading.
- 2) Each tap gain process is independent of the others.
- 3) Each tap gain process has a bandpass filtered Gaussian spectrum which defines the time correlation of the tap fading.

The Watterson channel transfer function is given by

$$H(f, t) = \sum_{i=1}^M w_i(t) \exp\{-j 2\pi f \tau_i\}$$

where M is the number of paths, τ_i is the delay of each path and $w_i(t)$ is the random tap gain.

The S250C uses Watterson's basic model, but departs slightly regarding the third tap-weight constraint. Watterson requires that the process spectrum be Gaussian, but for the sake of readily obtainable, stable filters with variable bandwidth we are less restrictive and employ Butterworth filters. Furthermore, the SIGNATRON implementation resolves the tap gain function into two component operators. (See Figure 1.4b.) A tap gain spectrum that is not centered on 0 Hz may be considered the product of a process whose power spectrum is centered on 0 Hz and a sinusoidal modulation at the offset frequency. The deterministic sinusoidal function is implemented as a gross Doppler shift while the random process, $w_i(t)$ yields phase variations that are treated as perturbations in the gross Doppler shift. The random process amplitude $|w_i(t)|$, controls the amplitude gain of path i . The bandwidth of the Butterworth filter determines the 2-sigma Doppler spread of the amplitude fluctuations, and can closely approximate Watterson's Gaussian fading spectrum.

The S250C is also capable of diversity operation (in the non-hopping mode). Each of the independent paths may be individually directed to either of two output adders, each adder being associated with an individual receiver. Two types of channel noise are available: additive Gaussian noise and/or additive impulsive noise. The Gaussian noise for receiver 1 is independent of the Gaussian noise for receiver 2. Impulsive noise can be random or periodic and is identical for both receivers. In addition, the S250C is capable of simulating additive interference (jamming) and interference due to unwanted RF intermodulation products.

The S250C allows the operator to select up to 6 paths with different fading rates (2-sigma Doppler), amplitudes and Doppler shifts. In addition, the operator can specify one or more paths to be non-fading (2-sigma Doppler = 0) in order to simulate HF/VHF groundwave, or VHF line-of-sight propagation with ground reflections.

Hopping HF Channel Model:

The hopping HF channel model is a modified Watterson channel model. The modified Watterson channel model has transfer function given by

$$H(f, t; f_k) = \sum_{i=1}^{M(f_k)} w_i(t, f_k) \exp\{-j2\pi(f + f_k)\tau_i(f_k)\}$$

where $M(f_k)$ is the number of paths at hopping frequency f_k , $w_i(t, f_k)$ is the complex random gain of the i 'th path at the hopping frequency f_k and $\tau_i(f_k)$ is its delay. Note that when there is only one hopping frequency, this model is identical to the non-hopping model. The user can specify different delays for each hopping frequency to simulate the frequency dependence of the various path delays which is observed in ionograms.

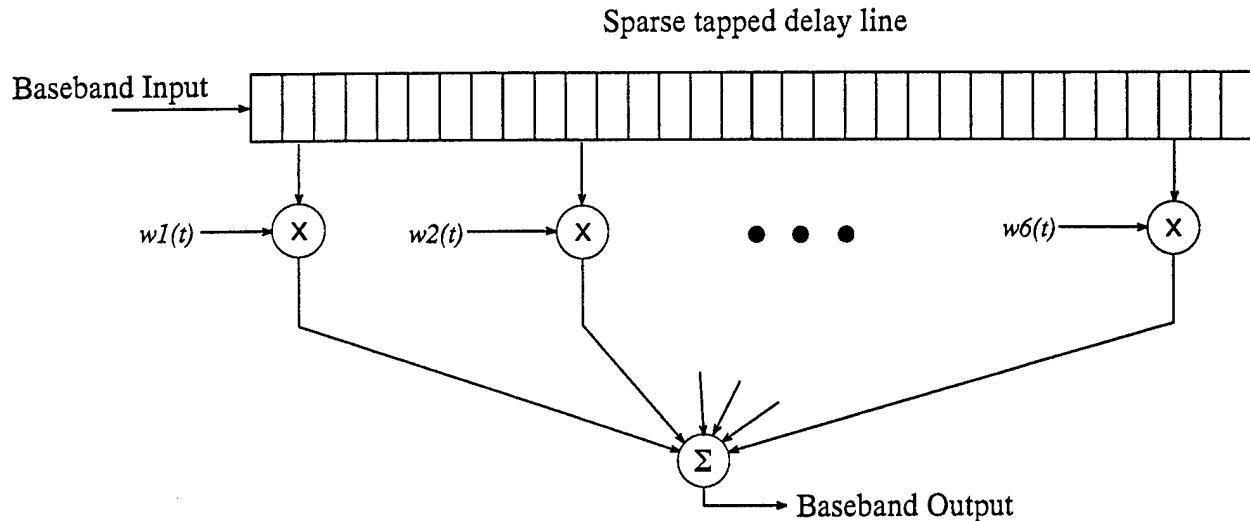


Figure 1.4a Watterson Channel Model

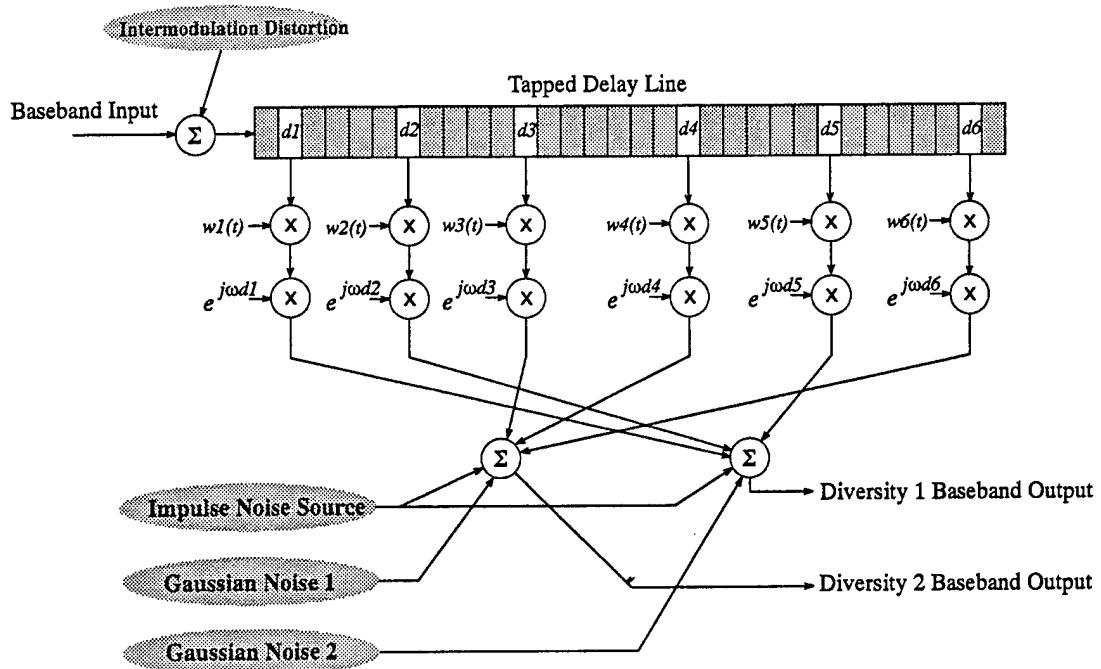


Figure 1.4b S250C Channel Model With Dual Diversity Capability

Simulation of realistic HF channels also requires that the complex tap gains at two different hopping frequencies, f_k and f_{k+n} , exhibit the proper frequency correlation, induced by the micromultipath structure around each path. It is reasonable to expect path characteristics at two adjacent hop bands to be somewhat related while path characteristics at two widely separated hop bands would tend to evolve independently of each other, even when delays are identical. Hence the S250C simulates the frequency correlation of the tap gains at different hopping bands as

$$E\{w_i(t, f_k) \cdot w_i^*(t, f_{k+n})\} = e^{-\left(\frac{|f_{k+n} - f_k|}{B_i}\right)}$$

where $E\{\cdot\}$ denotes averaging over the complex Gaussian statistics of the fading, and B_i is the decorrelation bandwidth for the i 'th path which is specified by the user.

In the hopping mode, the S250C also allows the user to apply different signal-to-noise ratios in each of the hopping bands.

In summary, the S250C simulates the appropriate time and frequency correlation of the HF channel fading. It also allows the user to specify the time and frequency correlation.

1.5 ROAD MAP

1.5.1 This Manual

This user's manual covers the information needed for normal simulation operation. In Section 2, the operation of GENPAR, the simulation parameter generation program, is discussed in detail.

Section 3 covers by example the actual running of a simulation with the run time program HFSIM using GENPAR files.

Section 4 describes how to obtain estimated simulation parameters for a given HF link using HFPRED.

Section 5 is an overview of the Theory of Operation of the simulation and summarizes key implementation details that may impact the simulation.

1.5.2 Other Manuals

Standalone manuals include the following:

- Hardware Description and Maintenance Manual (volumes I through XI)
- S250C Software Theory of Operation Manual
- S502B Frequency Hop Translator Manual
- Test Plan for S250C HF/VHF Channel Simulation
- AST Computer Manual and Documentation
- Spectrum DSP Manual and Documentation
- Greening PC-AT to VME Adapter Documentation

SECTION 2
GENPAR**2.0 OVERVIEW**

GENPAR is a menu-driven user interface designed to create and edit parameter files and master files needed to use the simulator program HFSIM. Except for the fact that only one file at a time may be active, the user is free to run GENPAR in a number of different ways. A master file may be created or edited, and edits may be saved in the same or in a new file. For a parameter file, after first specifying some general information, the user may enter or change previously entered data in any order desired, with very few exceptions. A file for such data may be opened before, after or during data entry. GENPAR can also perform some DOS functions during a parameter file editing session.

When GENPAR is invoked by typing "GENPAR", followed by pressing the Enter key, the menu in Figure 2.1 is displayed. When selected, each of the four menu items furnishes a pull-down window, and each window has a list of options from which to choose. The first window on the left has options pertaining to parameter files, master files, DOS functions and quitting GENPAR. All remaining windows have options relating to parameter files only.

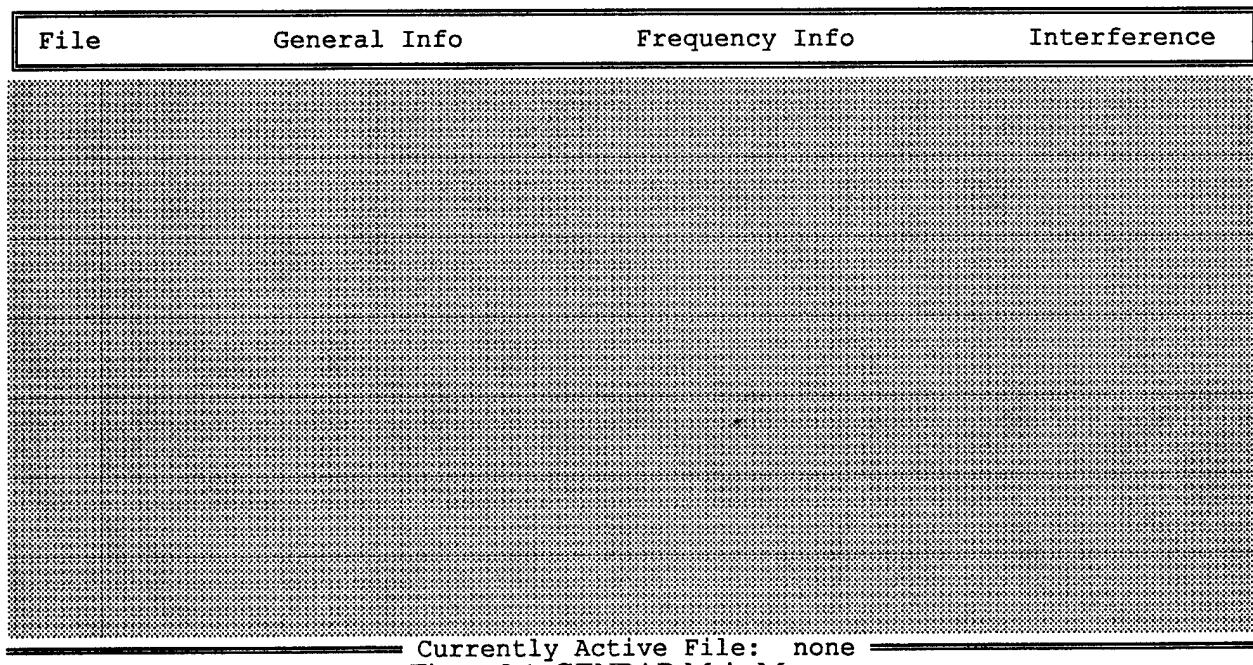


Figure 2.1 GENPAR Main Menu

The user can select an item or option in one of three ways: moving the highlight bar over the option using the UP, DOWN, RIGHT and LEFT cursor keys, pressing the key corresponding to the yellow letter in an option's name called its "hot key", or moving the red cursor to it and clicking with the left-hand button of the mouse, thus highlighting the item. In this way, the user chooses the next item or option. The user can get back to the previous level at any time by pressing the Esc key or clicking the right-hand button of the mouse.

Virtually every GENPAR option displays a form on the screen when selected. A form is a page of prompts and data fields for the user to complete. A few options like "Restore last save" put up a small form just to ask for a confirmation of the action. "Close" is the only option which displays no form at all and "Save" displays a form only if no parameter file is active.

The purpose of each form is to collect data such as directory and file names to open a file or the specifications of a jammer for a parameter file. Except for the file forms, each parameter file data field has a default value in it when a form is first displayed. These values are known as the "forms defaults". In addition to defaults, each field has an acceptable range of values or list of values. During each field edit, GENPAR tests for validity and sends the user a message if it encounters an unacceptable entry (Figure 2.2). NOTE: The user is advised not to use the "Leave Unanswered" option since the result is a blank field whose internal value to GENPAR is zero. The field can be restored, however, by beginning a new edit in it.

In general, the user can make his way among the form fields in any order by using the mouse or by using the cursor keys of the keyboard. Field edits should be terminated by pressing the Enter key. Under some circumstances the left-hand mouse key would perform the same function, but the keyboard key always has the desired effect. If the field edit has not yet been terminated, the default field value when the edit began can often be retrieved by pressing the F7 key.

Note that clicking with the mouse generally is equivalent to pressing the Enter key on the keyboard and that the right-hand button of the mouse is equivalent to pressing the Esc key. These buttons have analogs in software in that the white fields such as "Esc=Cancel" at the bottoms of forms are known as buttons also and are "pressed" by clicking on them with the left-hand mouse button. In this section,

<xx> means the corresponding button or keyboard key; "press <F2>" is then equivalent to clicking on the F2 button of the form or pressing the F2 key on the keyboard.

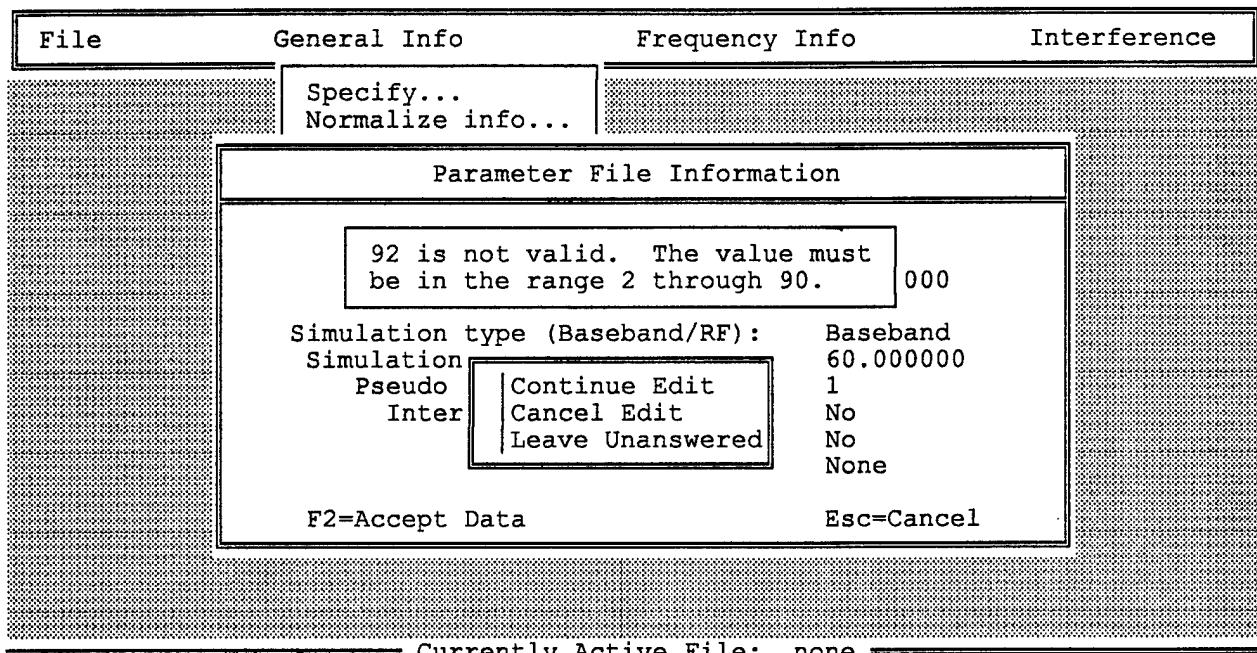


Figure 2.2 Invalid Entry Message Form

All forms have an Esc button on the bottom and most have an F2 button as well. The Frequency Page Information form has the largest number of buttons by having six. <Esc> always has the same meaning - that of canceling the current form and returning to the previous level which may be the last form or the main menu. In some forms <F2...> means to take an action such as "Read" the specified file in while in others <F2...> means to "Accept" the data now in the form field as the current valid data. In either case, <F2> is the action button and should be pressed whenever the user has completed a form and wishes to approve it.

Note that "Accept Data" does not mean the same thing as a save to file; it just means that if the user calls up the form again, the last accepted data will be in the form field and that, if a save is done, this is the data that will be written out to the file. Note that the form field will not be saved if <Esc> is pressed but only if <F2...> is pressed. The user is also free to re-edit any form after its data has been accepted and to "re-accept" it.

Periodically, when necessary, GENPAR will ask for confirmation of an action by displaying a form with a question and the obvious choices of YES and NO. In addition, there is an implicit third choice of pressing `<Esc>` which, in almost all cases, is equivalent to selecting NO. In other words, the action will take place only if the user selects YES. The `cLose` (file) option is the only exception.

Confirmation is requested for a save to file before closing. A response of YES results in a save before closing, NO results in no save before closing and <Esc> cancels the cLose command. In this case <Esc> and NO have different meanings.

The user can terminate GENPAR by selecting Quit or by just pressing <Esc>. Either action will cause a save to file confirmation form to be displayed (Figure 2.3). Answering in the affirmative will result in a save, and a NO or <Esc> cancels the request.

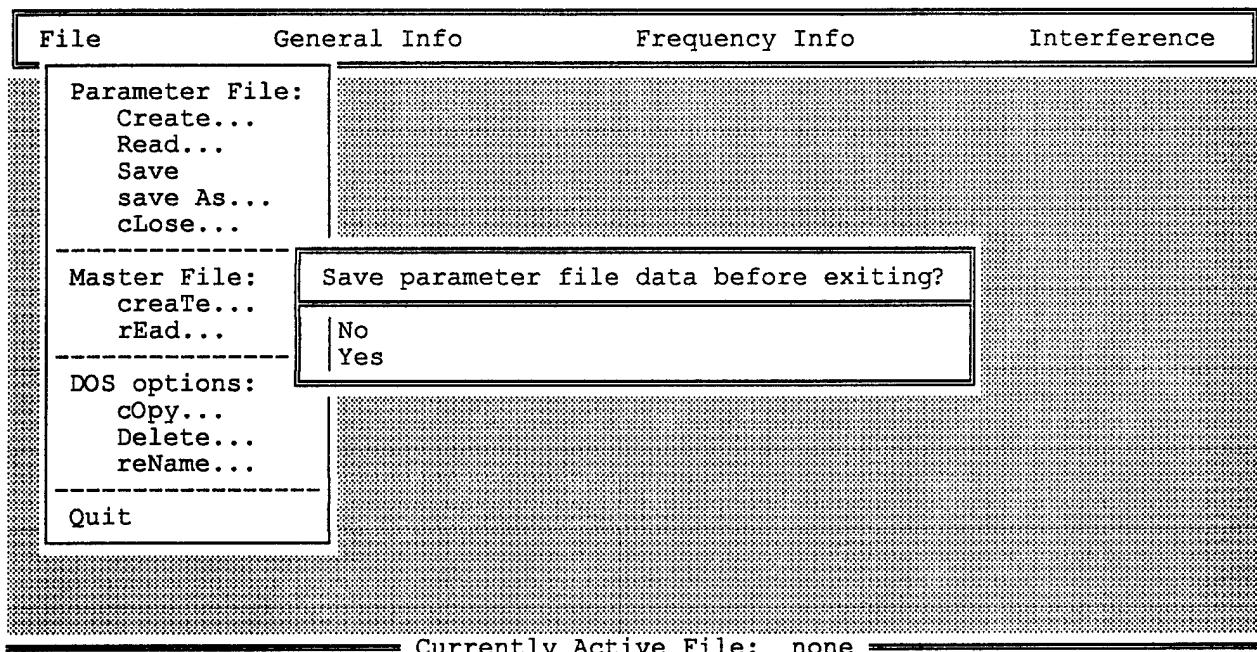


Figure 2.3 Confirmation Form

2.1 FILE WINDOW

File window options (Figure 2.4) are broken down into four categories: Parameter File, Master File, DOS options and Quit.

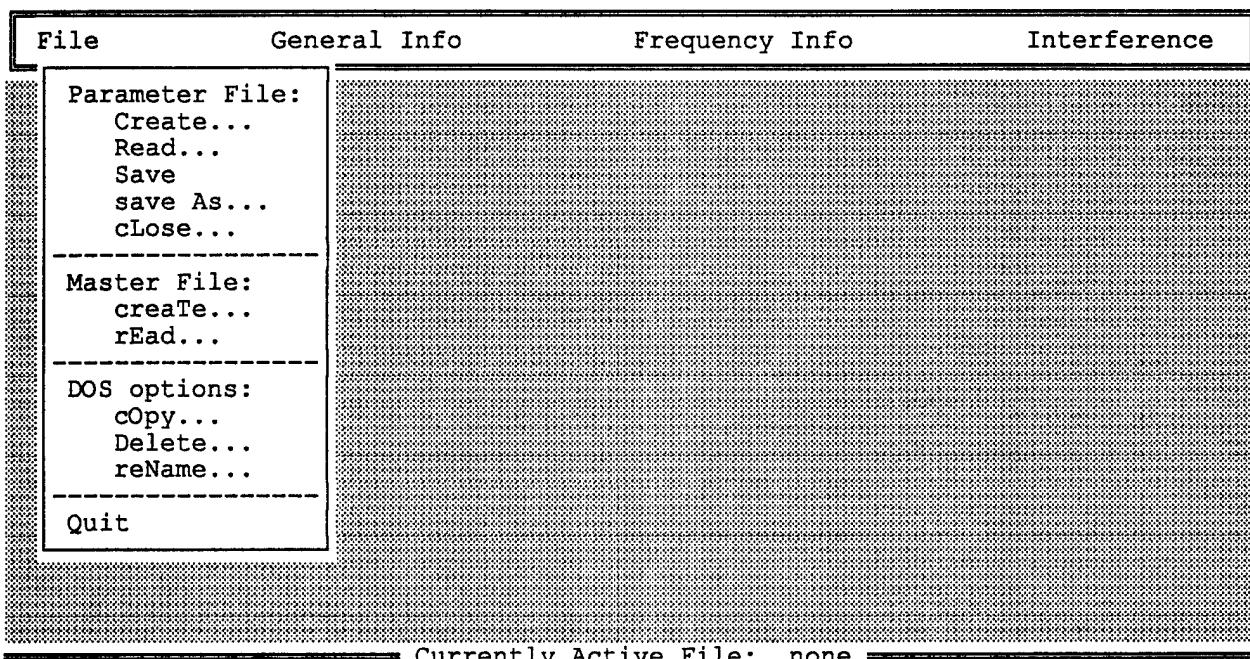


Figure 2.4 File Window

GENPAR is designed to have at most one file, either parameter or master, open at the same time. The name of this current file is displayed after the caption "Currently Active File: " on the bottom line of the screen.

In all of the options involving file actions, the user can select both a directory and a file either by using the directory list brought up by selecting the "<view>", "<view directory>" or "<select from directory>" field or by typing in the desired directory or file name. The list always has the current directory's parent directory at the very top with the name "PARENT <DIR>" (unless it is the root directory) and subdirectories, if any, right after that - those with the label "<DIR>" on the right. The list of files in the current directory are arranged alphabetically by name.

If the user selects a directory while in a file form, the default directory actually changes to that directory and will remain in effect for the remainder of that GENPAR session unless changed again by the user. However, upon exit, GENPAR changes the default directory back to the directory the user was in when GENPAR was invoked.

2.1.1 Parameter File Category

Figures 2.5, 2.7 and 2.9 correspond to the options Create, Read and Save As, respectively. Any action resulting in a file open is followed by the file name appearing at the bottom of the screen and by returning to the menu. The cLose option indicates on the bottom line that no file is active by changing the message to "Currently Active File: none". For Create, Read and Save As, <Esc> will return the user to the menu with no file action at all.

2.1.1.1 Create Option

The Create form (Figure 2.5) is used for opening a new parameter file of the specified name in the specified directory. Figure 2.6 shows the directory list resulting from selecting the <view directory> field. "View" is intended to imply that only a new file name is expected for this form and that viewing will help the user to avoid choosing an existing file name. After entering a new file name or editing an old one to obtain a new name, pressing <F2=Create> is necessary for the open to actually take place.

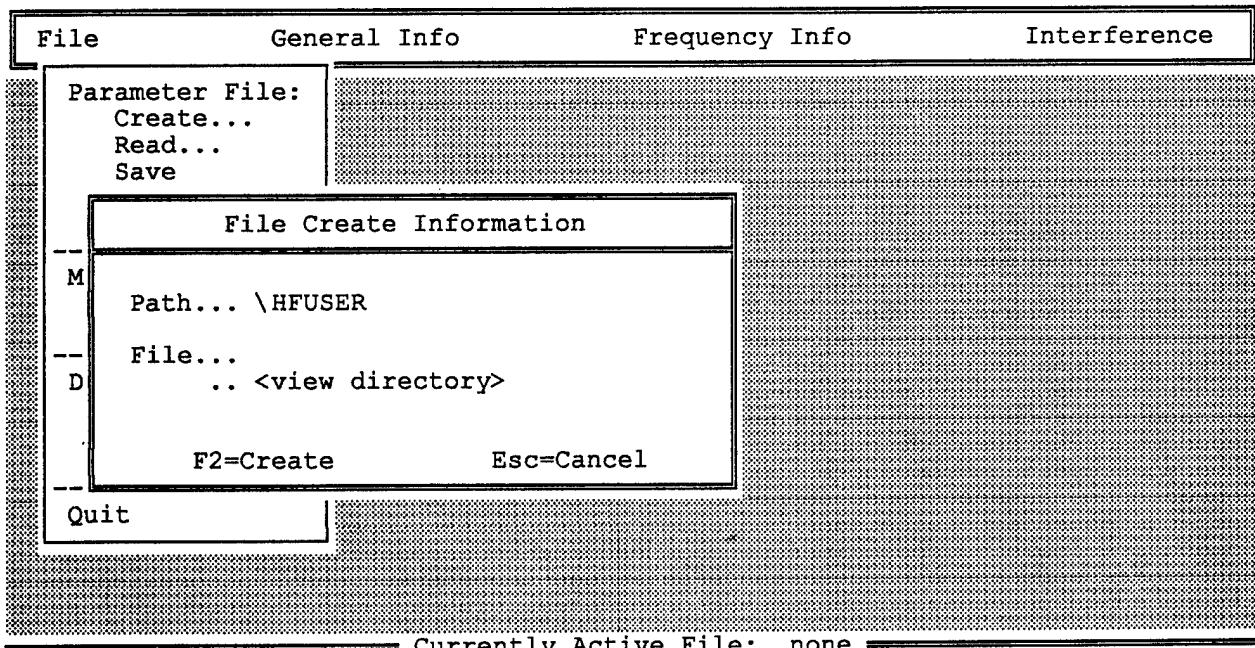


Figure 2.5 Create Parameter File Form

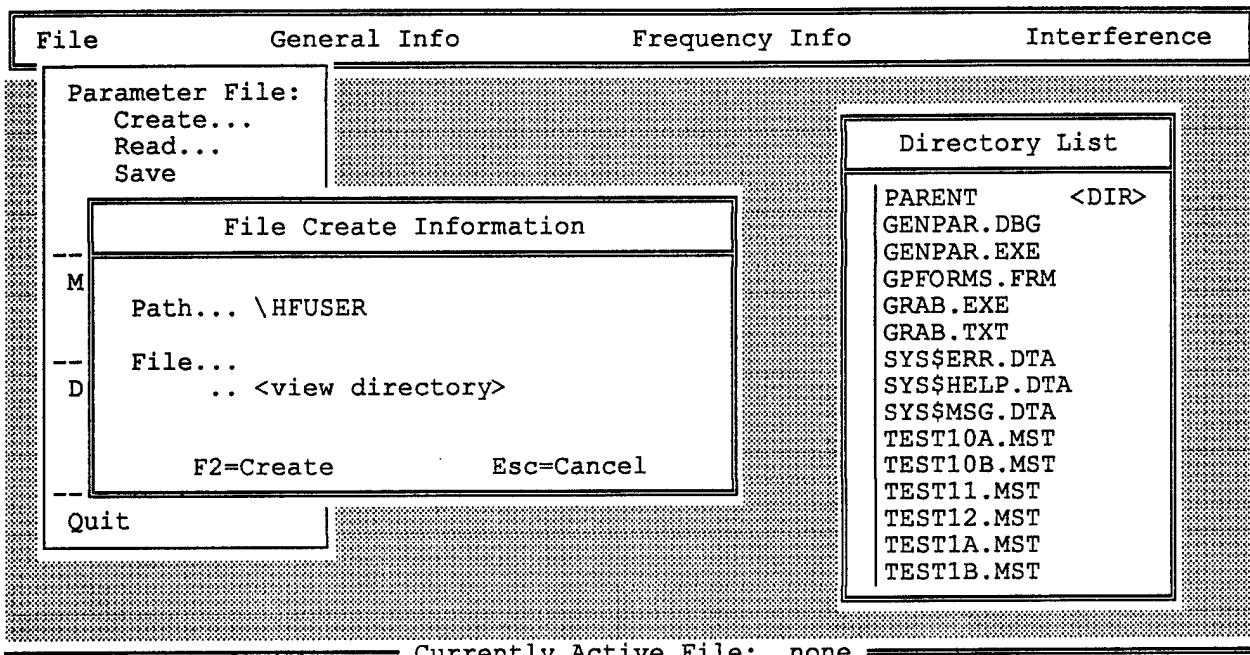


Figure 2.6 Create Parameter File Form With Directory

2.1.1.2 Read Option

The Read form (Figure 2.7) is used for opening an existing parameter file with the specified name in the specified directory. Figure 2.8 shows the directory list resulting from selecting the <select from directory> field. "Select" is intended to imply that only an old file name is legal for this form. After entering the file name of an existing parameter file, pressing <F2=Create> is necessary for the file to actually open.

2.1.1.3 Save Option

Save gathers all of the parameter data presently in the forms and writes it out to the currently open file. If there is an active parameter file, Save displays no form before writing data. If there is no file active, selecting Save is equivalent to selecting save As (2.1.1.4) except that Save does not close the current file. NOTE: Save normalizes all signal, noise and interference amplitudes before writing data out to the file. Therefore, a save should never be done if the user is not finished entering or editing all amplitudes in all forms.

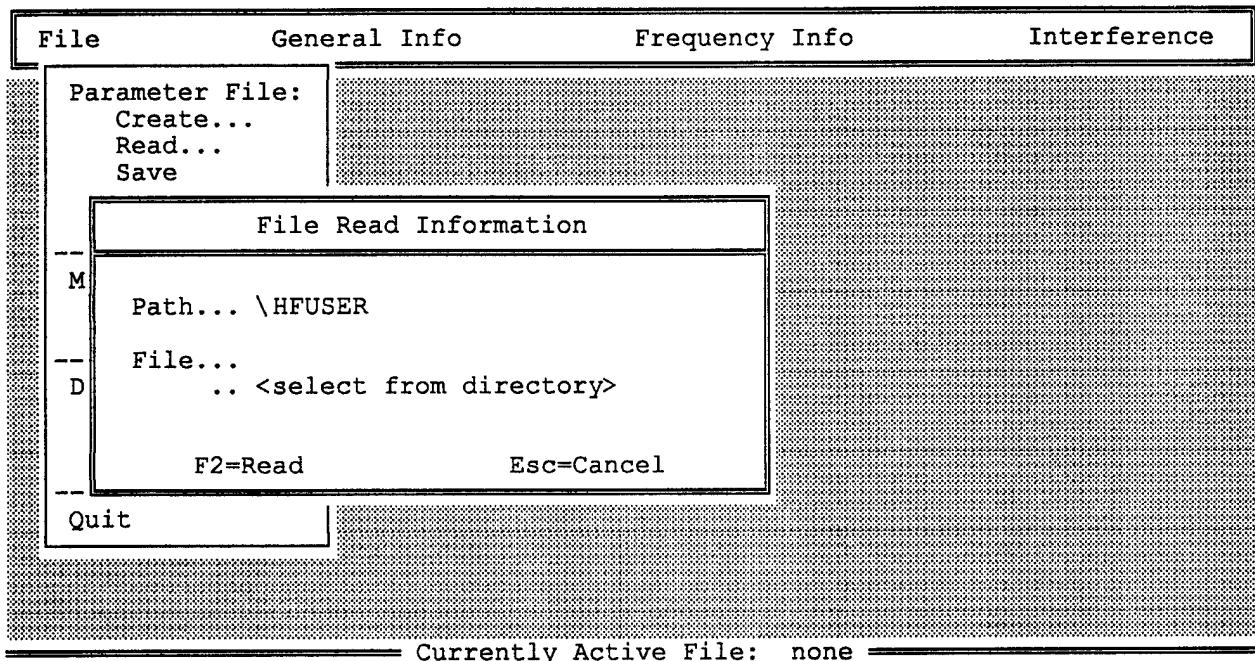


Figure 2.7 Read Parameter File Form

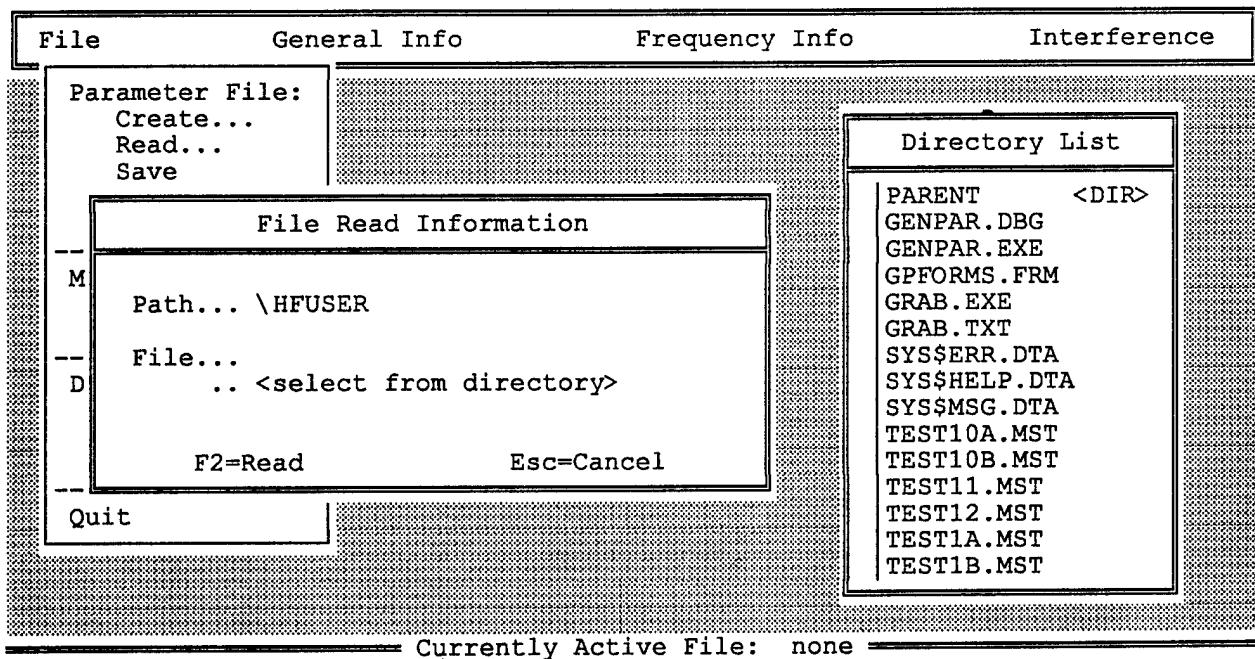


Figure 2.8 Read Parameter File Form With Directory

2.1.1.4 save As Option

Save As (Figure 2.9) opens a new or an existing parameter file with the specified name in the specified directory, saves all data and closes the file. Figure 2.10 shows the directory list resulting from selecting the <directory> field. <directory> with no qualifier is meant to imply that a save file may be old or new. After entering the file name of a parameter file, pressing <F2=Save> is necessary for the open and save to actually take place. Save As is essentially a Create or a Read followed by a Save.

2.1.1.5 cLose Option

There is no form for the cLose option. If there is no file active, cLose only gives a message to that effect. If there is an active file, the user is asked to confirm a save before closing. A response of YES results in a save before closing, No results in no save before closing and <Esc> causes neither to happen.

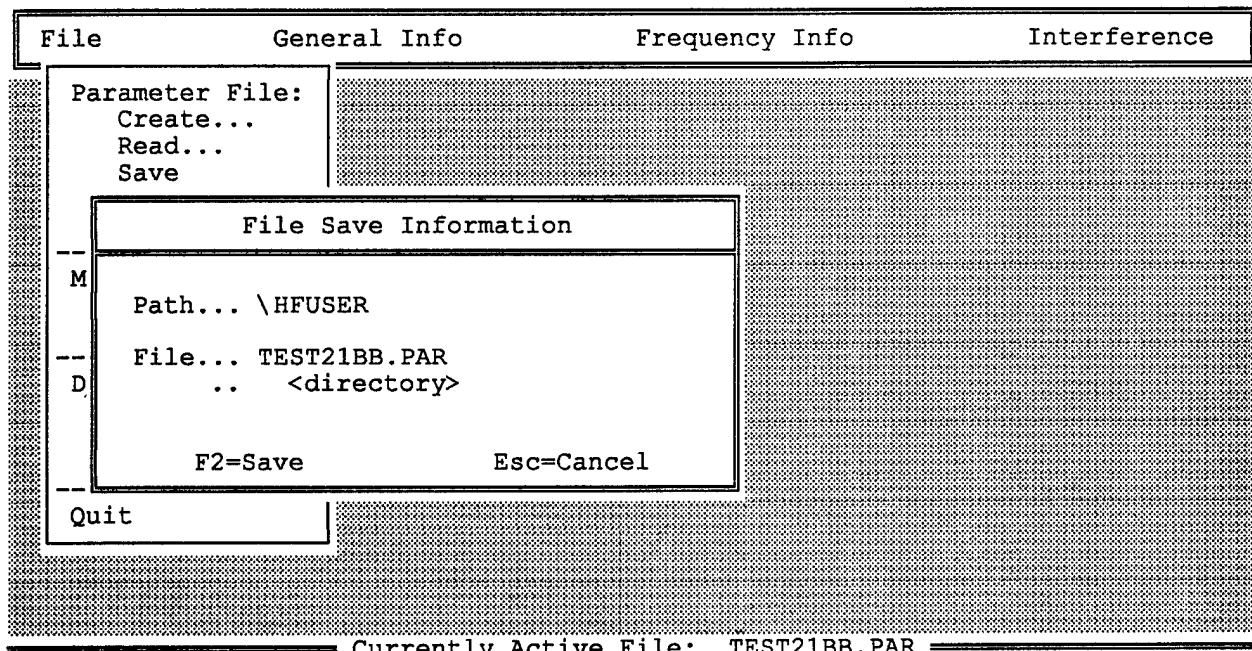


Figure 2.9 Save As Parameter File Form

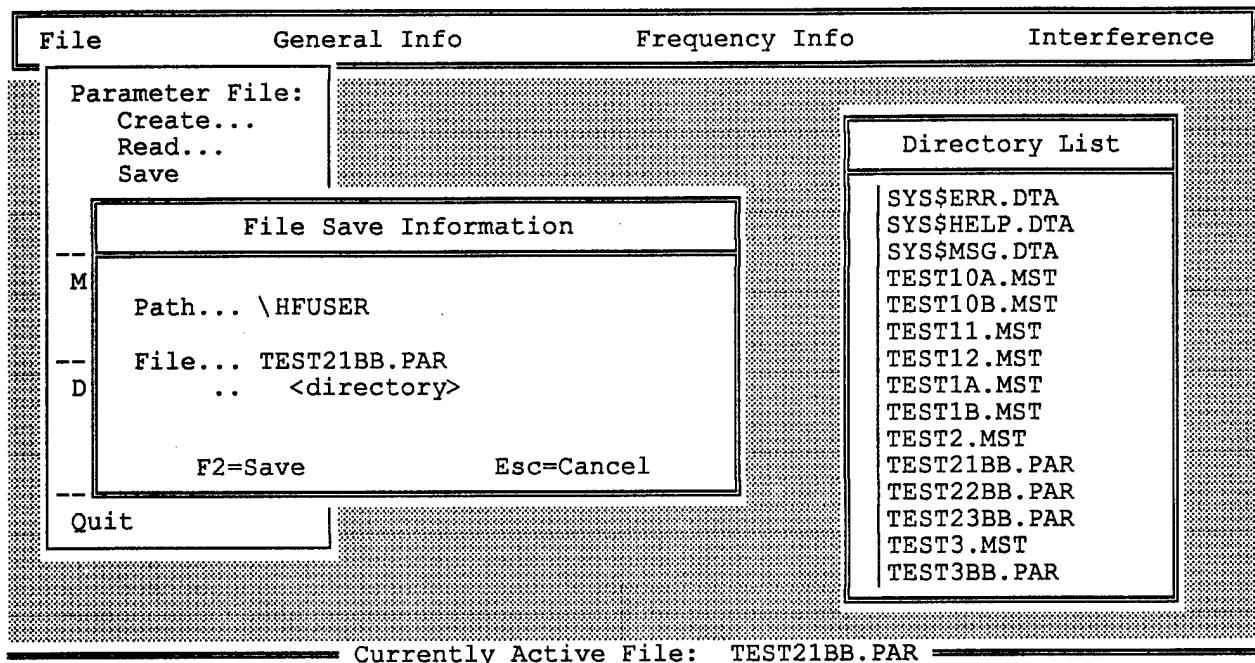


Figure 2.10 Save As Parameter File Form With Directory

2.1.2 Master File Category

Master file **creAtE** and **rEad** options display the same forms as the parameter files for obtaining file names. Similarly, in both cases, when **<F2...>** is pressed after entering a valid file name, that name appears as the currently active file at the bottom of the screen. However, GENPAR does not return to the menu at this point, but rather a text editor form is superimposed on the file form (Figure 2.11).

If the file is new, the form is empty and the user can simply type the desired text onto the screen, using the labeled keys on the keyboard to delete characters and to move around in the text (Figure 2.12). If the file is old, GENPAR reads the text into the editor which the user may now edit. At the end of an editing session the user presses **<Esc>** and will be prompted for the next action if there were any edits. If there were no edits, the file is closed and control is passed to the main menu again. If any edits are detected by GENPAR, the user is asked if a save is necessary (Figure 2.13). If so, another confirmation form checks for another or the same master file (Figure 2.14). If another file is to be opened for the save, a save As file form is displayed. Figure 2.15 shows the save As file form when **<directory>** is selected. "**<directory>**" with no qualifier is meant to imply that a save file name may be old or new. If the user presses **<F7>** instead of **<Esc>** after editing, the cancel confirmation box in Figure 2.16 is displayed.

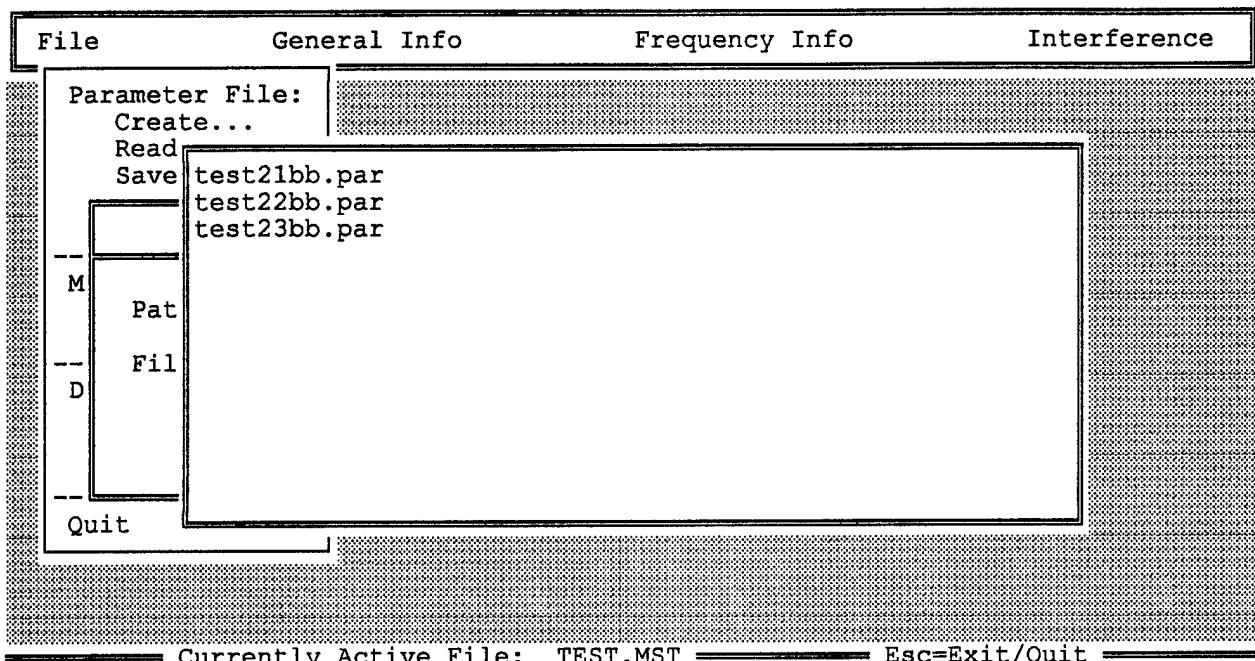


Figure 2.11 Master File Editor - Existing Text

ESCAPE	Escape	Back up to the previous level.
CANCEL	F7	Cancel markings or edit changes.
BACKSPACE	Backspace	Delete the character to the left of the cursor.
DELETE	Delete	Delete an item.
MARK	F5	Toggle marking for current item in editor.
UP	Up	Move up one line.
DOWN	Down	Move down one line.
LEFT	Left	Move left one position.
RIGHT	Right	Move right one position.
UP	PgUp	Move up one screen height.
DOWN	PgDn	Move down one screen height.
SPECIAL UP	Ctrl PgUp	Move to the very beginning.
SPECIAL DOWN	Ctrl PgDn	Move to the very end.

Figure 2.12 GENPAR Major Editing Keys

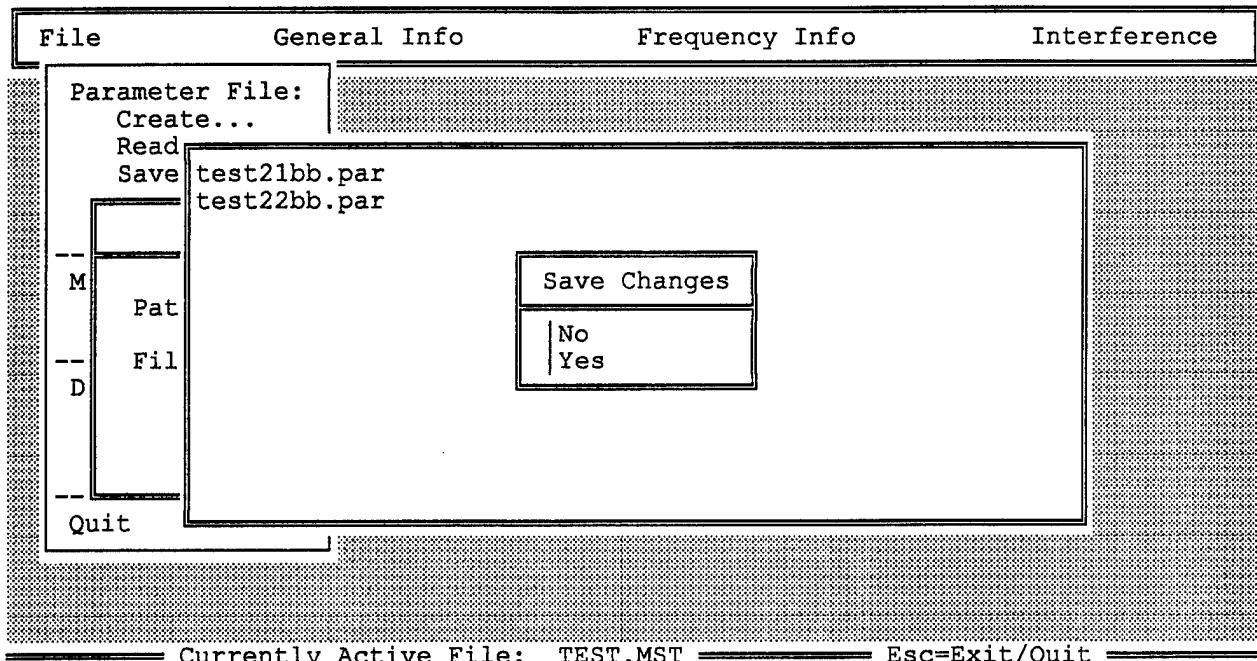


Figure 2.13 Master File Save Confirmation Form

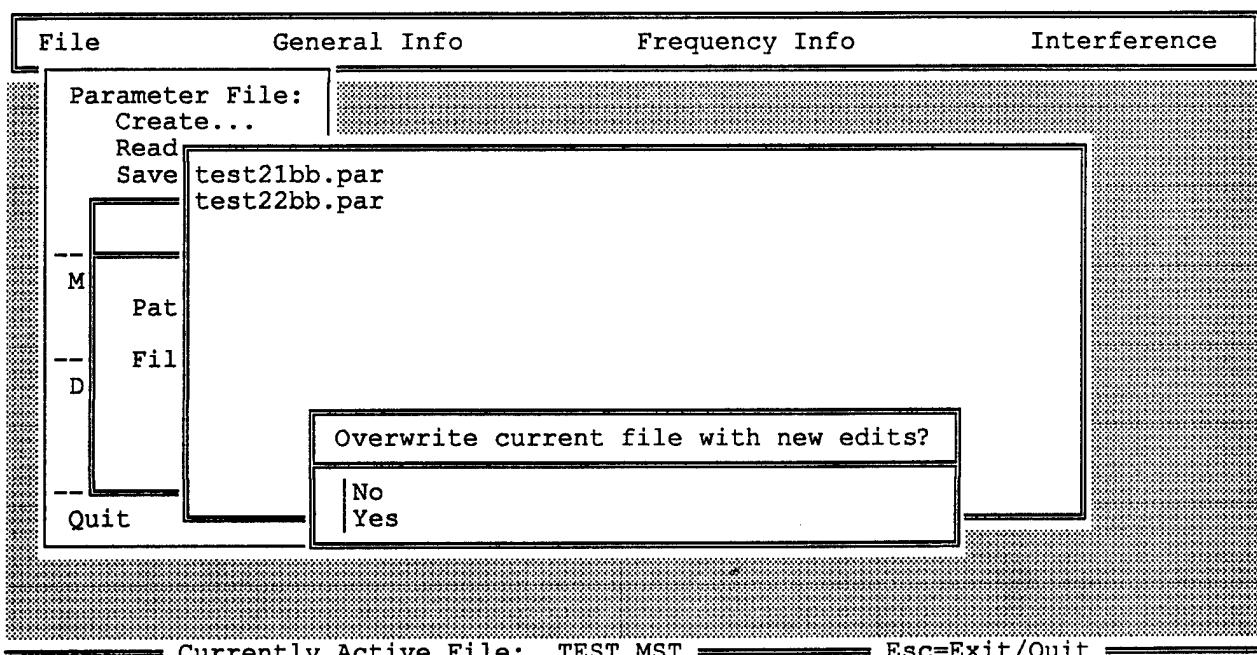


Figure 2.14 Master File Overwrite Confirmation Form

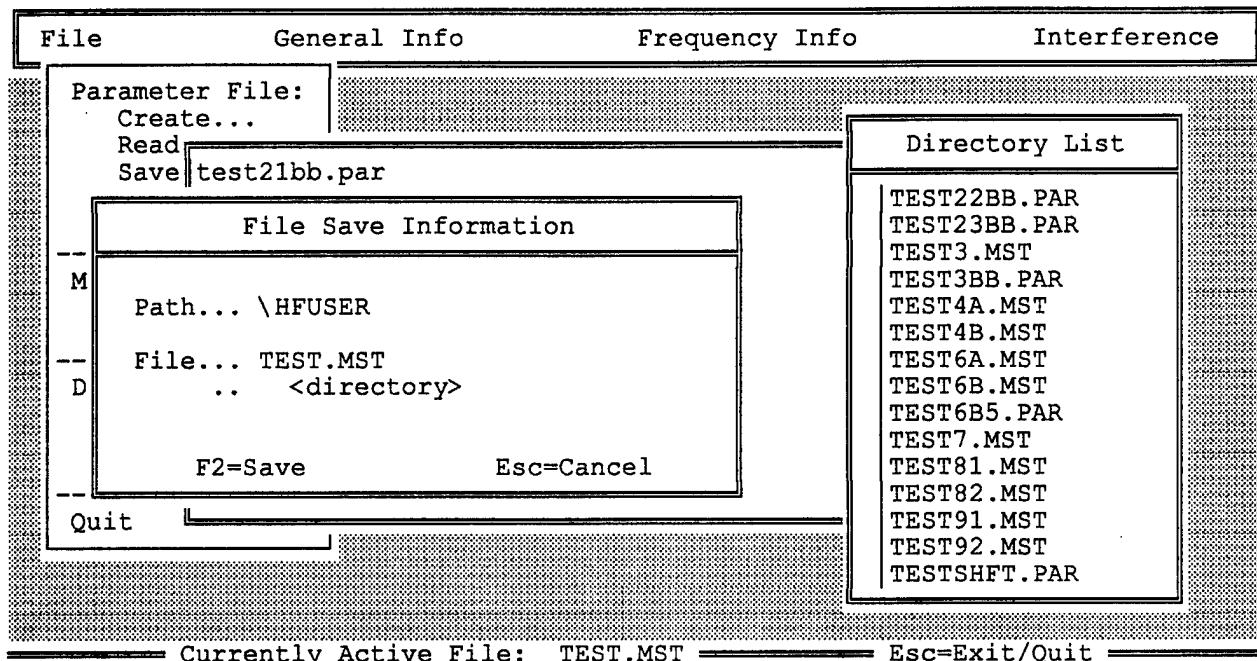


Figure 2.15 Master File Save As Form With Directory

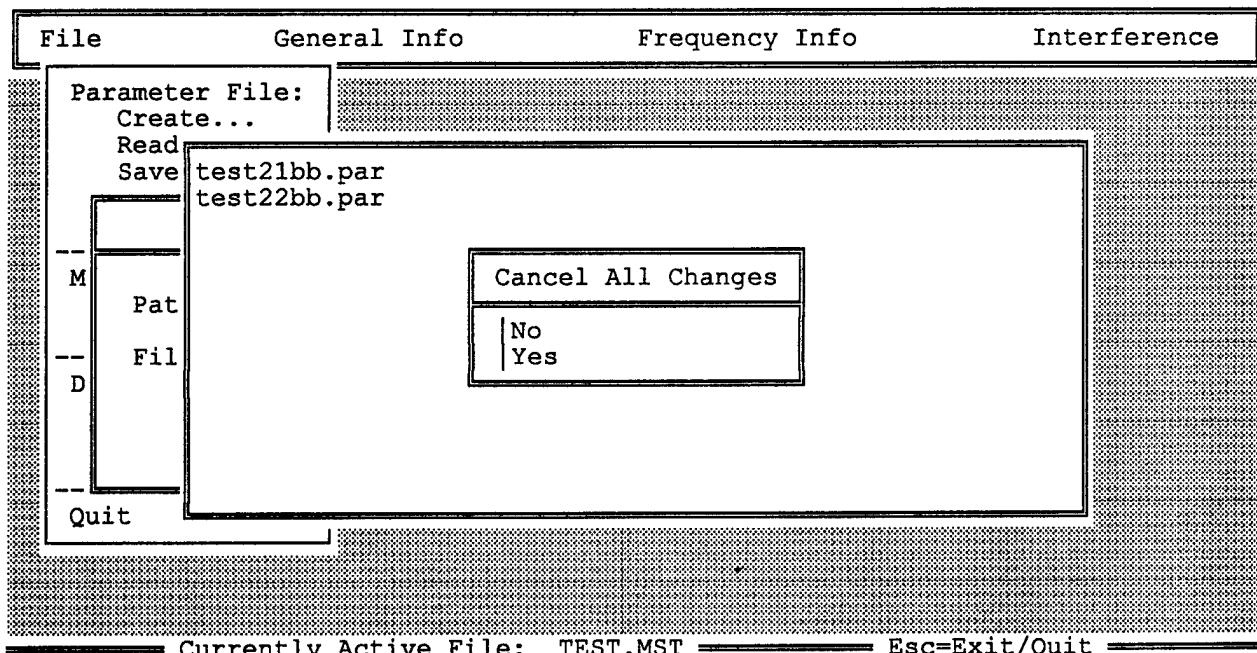


Figure 2.16 Master File Cancel Confirmation Form

2.1.3 DOS Options Category

The DOS options provided in GENPAR are cOpy, Delete and reName which, for the most part, work as expected. None of these functions cause the current file name to be updated at the bottom of the screen, but rather the names of the files manipulated remain internal to each form and action. In fact, these options can be used at any time during parameter file editing. As with the file forms, the last directory selected before returning to the menu becomes the latest default directory for GENPAR.

2.1.3.1 cOpy Option

The cOpy file form (Figures 2.17 & 2.18) first allows the user to view the current directory of subdirectories and files to select a directory and source file for copying. Next, the copy destination file can be chosen using the second directory list on the form. In this way, the file copy can take place across directories. The actual copying of the file starts after the user presses <F2=Copy>. The user is alerted if the source file was typed in and does not exist, and the form remains on the screen for correction. If the destination file already exists, a confirmation form is displayed for the user to verify an overwrite so that the copy occurs only if the user answers in the affirmative.

File	General Info	Frequency Info	Interference
Parameter File: []			
File Copy Information			
Copy from: Path... \HFUSER File... .. <select from directory>			
Copy to: Path... \HFUSER File... .. <view directory>			
F2=Copy		Esc=Cancel	

Currently Active File: TEST21BB.PAR

Figure 2.17 cOpy File Form

File	General Info	Frequency Info	Interference
Parameter File: []			
File Copy Information			
Copy from: Path... \HFUSER File... TEST21BB.PAR .. <select from directory>			
Copy to: Path... \HFUSER File... .. <view directory>			
F2=Copy		Esc=Cancel	

TEST2.MST
TEST21BB.PAR
TEST22BB.PAR
TEST23BB.PAR
TEST3.MST
TEST3BB.PAR
TEST4A.MST
TEST4B.MST
TEST6A.MST
TEST6B.MST
TEST6B5.PAR
TEST7.MST
TEST81.MST
TEST82.MST
TEST91.MST
TEST92.MST
TESTSHFT.PAR

Currently Active File: TEST21BB.PAR

Figure 2.18 cOpy File Form With Directory

2.1.3.2 Delete Option

The Delete form (Figures 2.19 & 2.20) allows the user to view the current directory of subdirectories and files to select a file for deletion. Deletion actually happens when the user presses **<F2=Delete>** and then answers the confirmation question in the affirmative.

2.1.3.3 reName Option

The reName form (Figures 2.21 & 2.22) appears similar to the cOpy file form, the major difference being that the destination file cannot already exist as in cOpy. The user is alerted if the source file was typed in and does not exist or if the destination file specified already exists; in each case, the form remains on the screen for possible correction. As with cOpy, reName will work across directories and, the file rename happens only after the user presses **<F2=Rename>**. The effect of reName is that a new file is made which is a copy of the source file, and the source file is deleted.

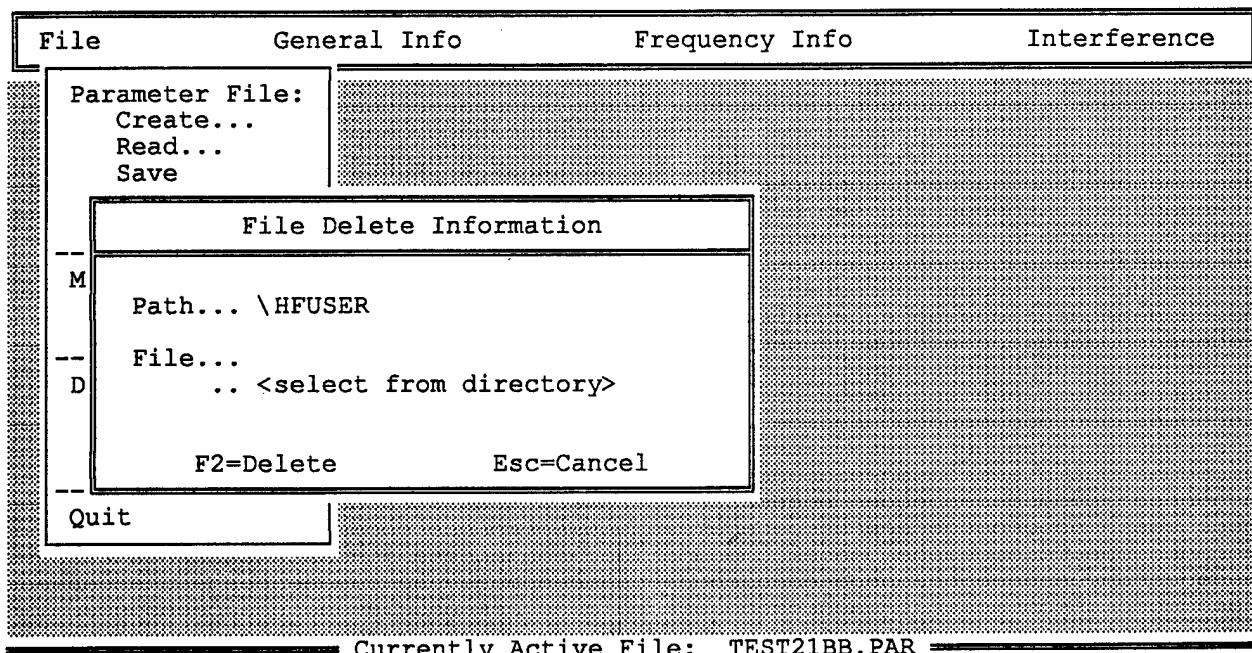


Figure 2.19 Delete File Form

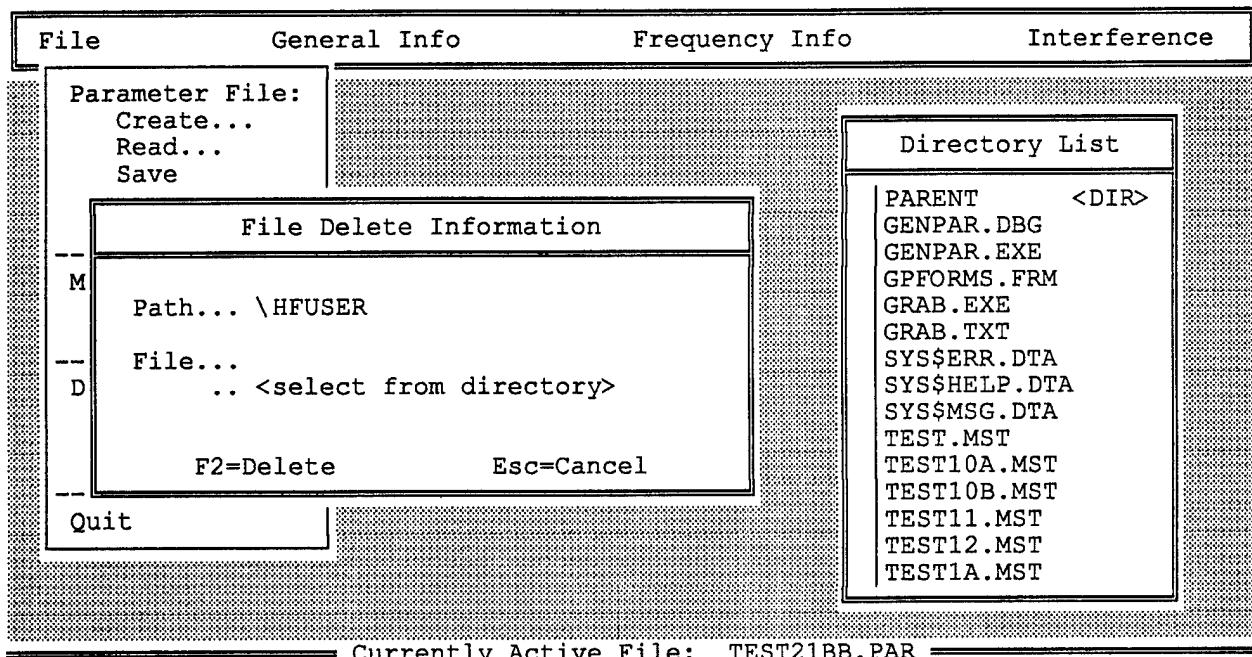


Figure 2.20 Delete File Form With Directory

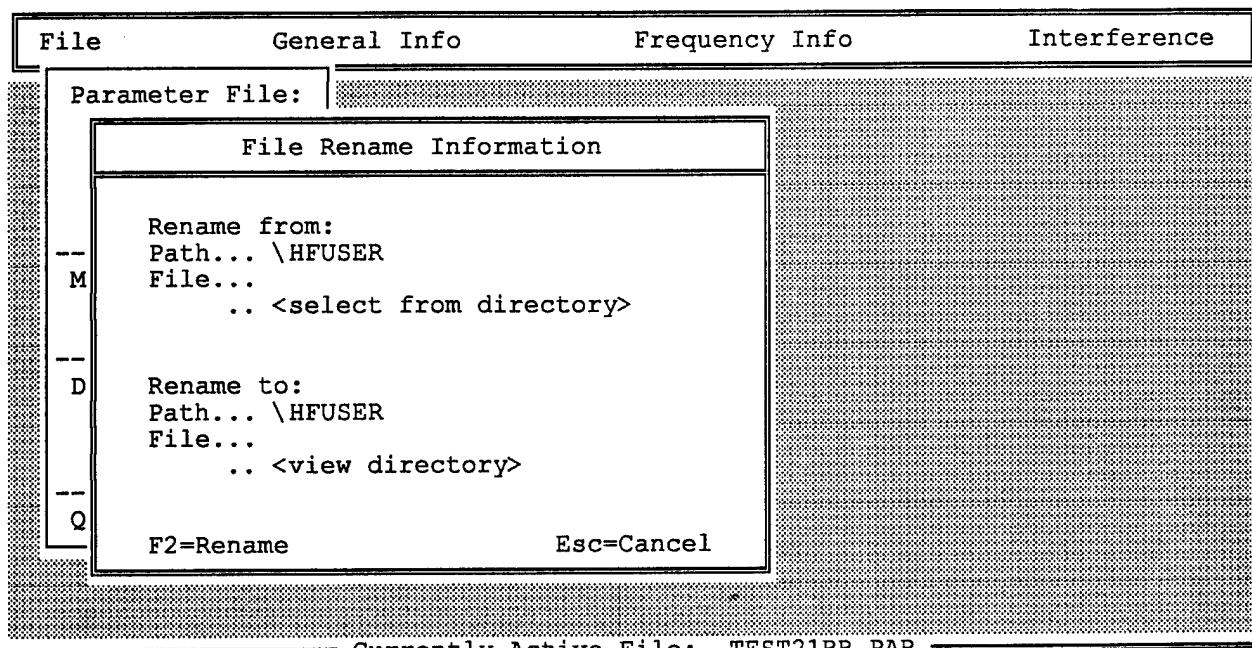


Figure 2.21 reName File Form

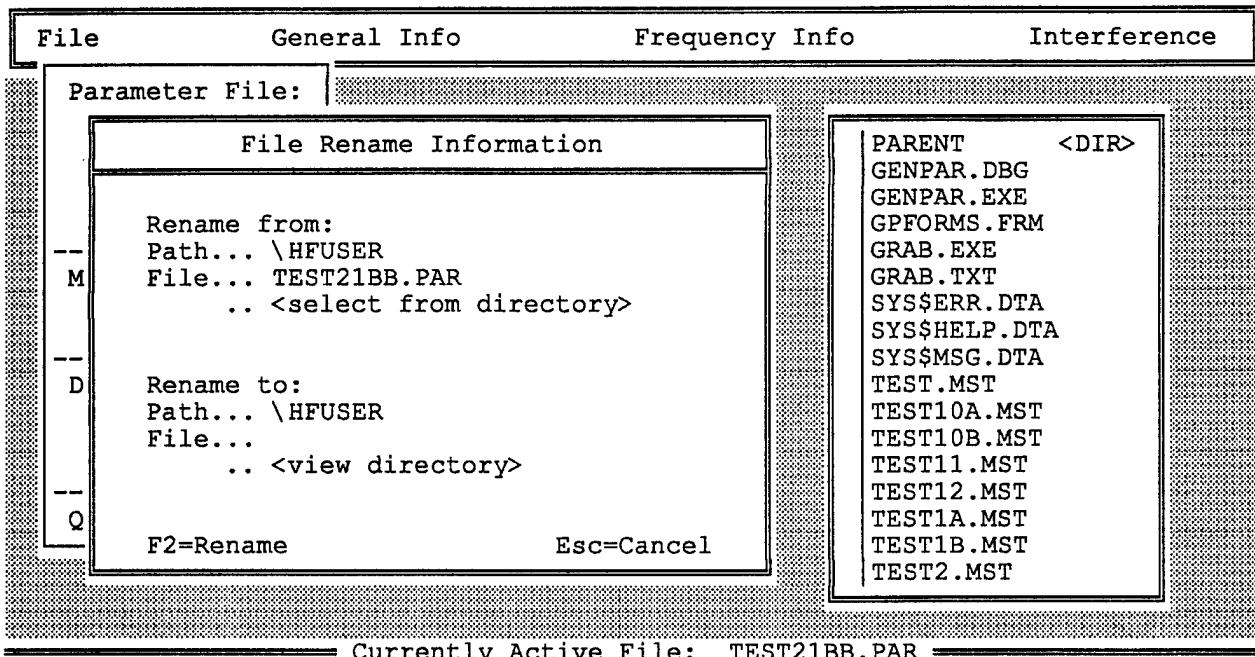


Figure 2.22 reName File Form With Directory

2.2 GENERAL INFO WINDOW

The forms displayed by the first three options in the General Info window, Specify, Normalize Info and Path Parameters, contain information which either affects the behavior of other parameter file related options or explicitly needs to be written to the current parameter file (Figure 2.23). The last two options, Forms Defaults and Restore Last Save are just convenient means to re-initialize the forms for the user and are not at all essential to the making of a parameter file. Again, as in most forms, <F2=Accept Data> must be pressed when the user approves the data or no entries will be saved.

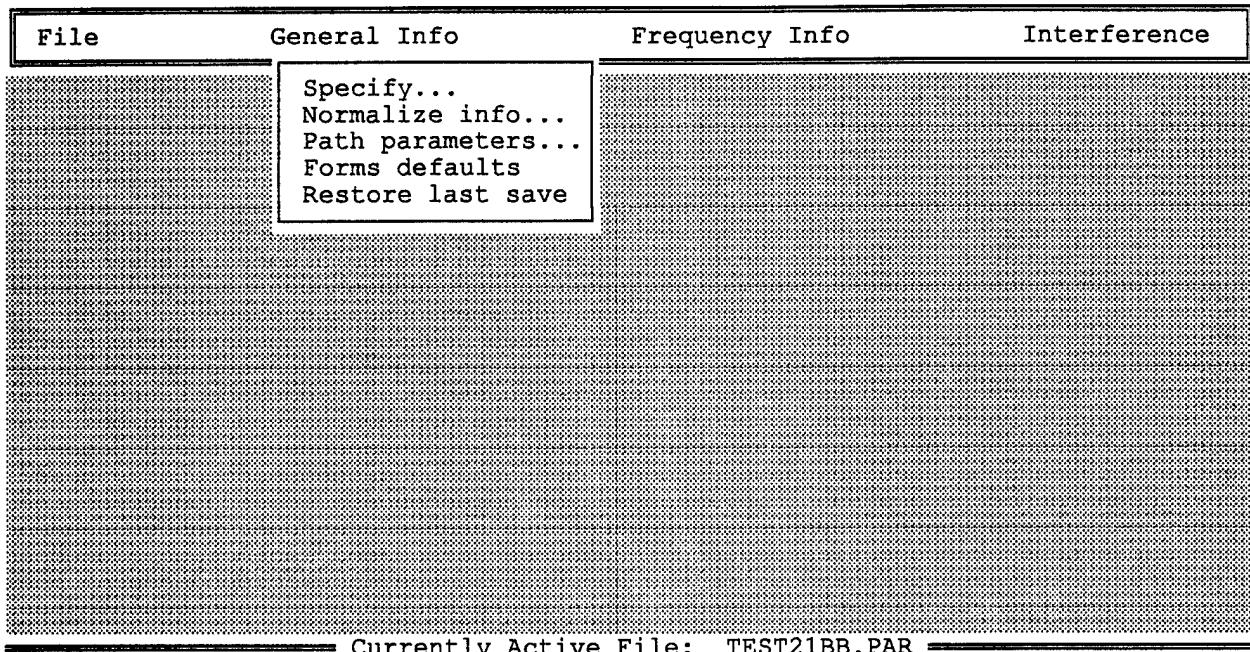
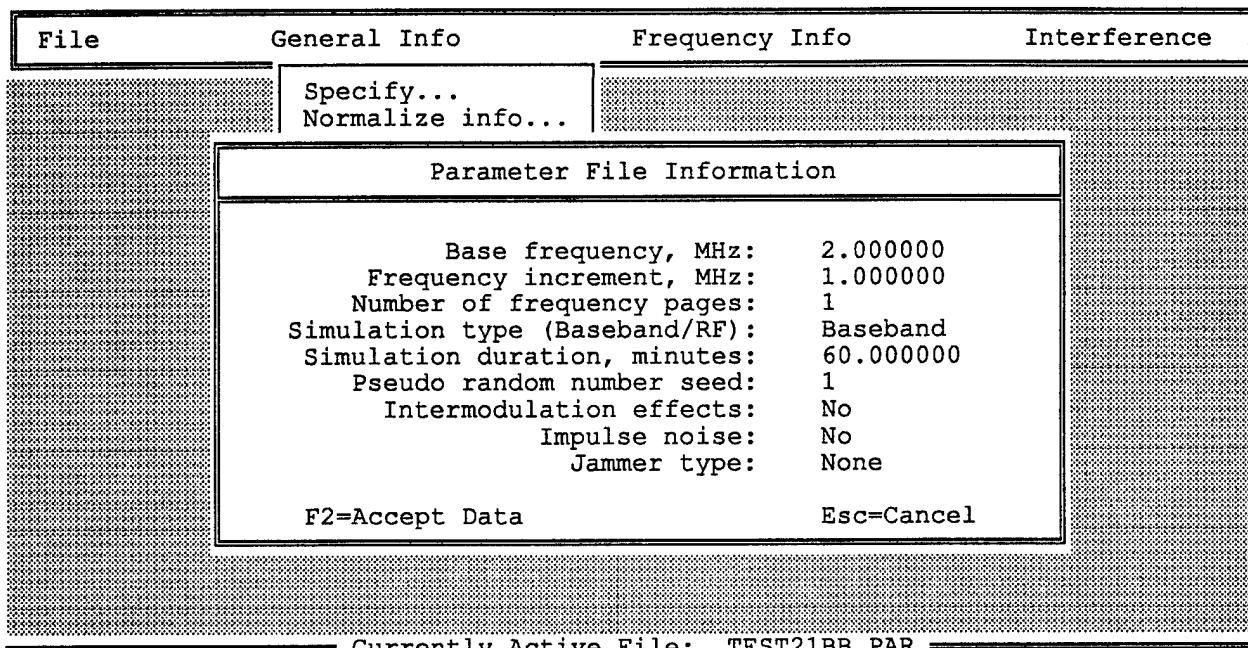


Figure 2.23 General Info Window

2.2.1 Specify Option

The Parameter File Information form (Figure 2.24) should always be filled out by the user at the start of a parameter file since many fields are fundamental to other parameter file values. The first three fields, which are all frequency related, affect fields in the frequency pages and other functions of GENPAR relating to the number of frequency pages.



Currently Active File: TEST21BB.PAR

Figure 2.24 Parameter File Information Form

The simulation type field toggles between its two values by means of either clicking on it or pressing a key OTHER than <Enter> on the keyboard. <Enter> in this case automatically causes movement to the next field, but it does not toggle values. This value as well as the intermodulation effects field setting and the jammer type affects normalization.

Jammer type is a list field and is displayed as a list when the field is selected (Figure 2.25). Selection of a list item displays that item in this field.

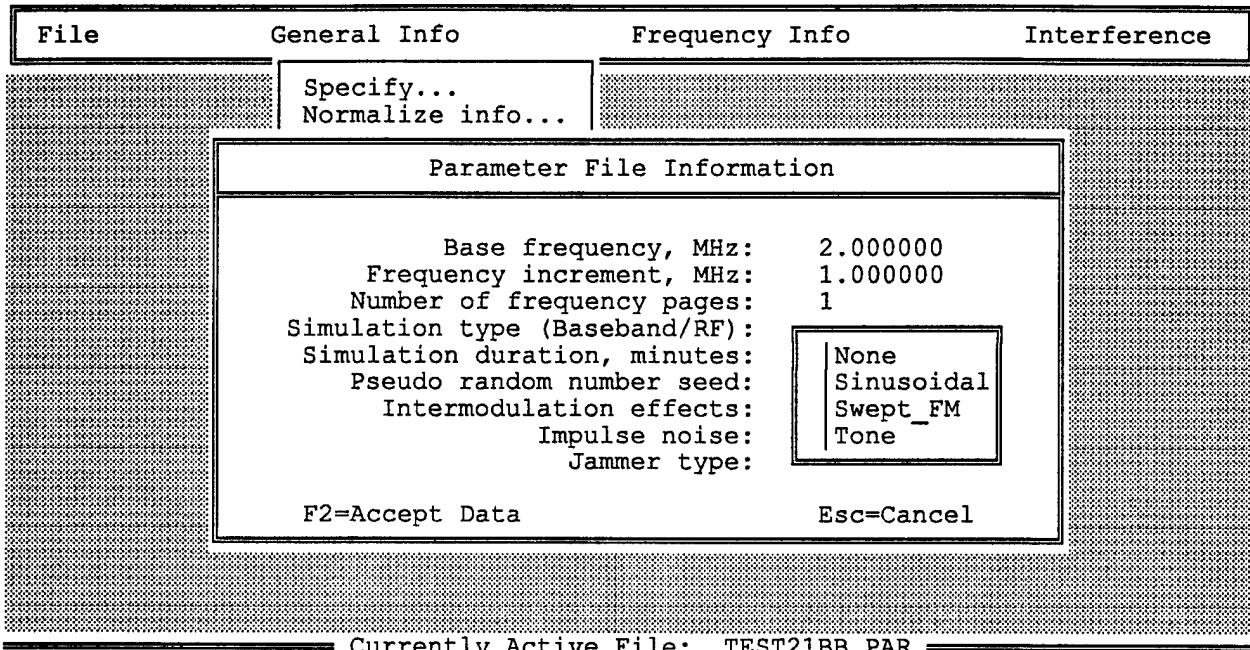


Figure 2.25 Parameter File Information Form With Jammer List

2.2.2 Normalize Info Option

Before normalizing all power data either by a save to file or by explicitly normalizing from a frequency page, the user should address the questions asked in the Normalize Info form (Figure 2.26):

GENPAR normalizes the output power by first computing the total output power at each frequency. After finding the maximum of these powers and calculating the amount this power exceeds 0 dBm, it subtracts this difference from every noise and signal power in the file. Should GENPAR normalize?

You should answer "Yes" to this question when all data have been defined.

If this difference falls below 0 dBm, should GENPAR normalize all powers up to 0 dBm?

You should answer "Yes" to this question when all data have been defined.

Generally, it is only necessary to answer "No" to these questions when saving in the middle of an editing session. For certain hardware tests, it may also be useful to leave the signals unnormalized.

As described, normalization preserves the relative strengths of the amplitudes over all frequencies. Note that if normalization is turned on, GENPAR will normalize when <F8> is selected from any frequency page form, and GENPAR will automatically normalize (without notice) at the start of every save to file.

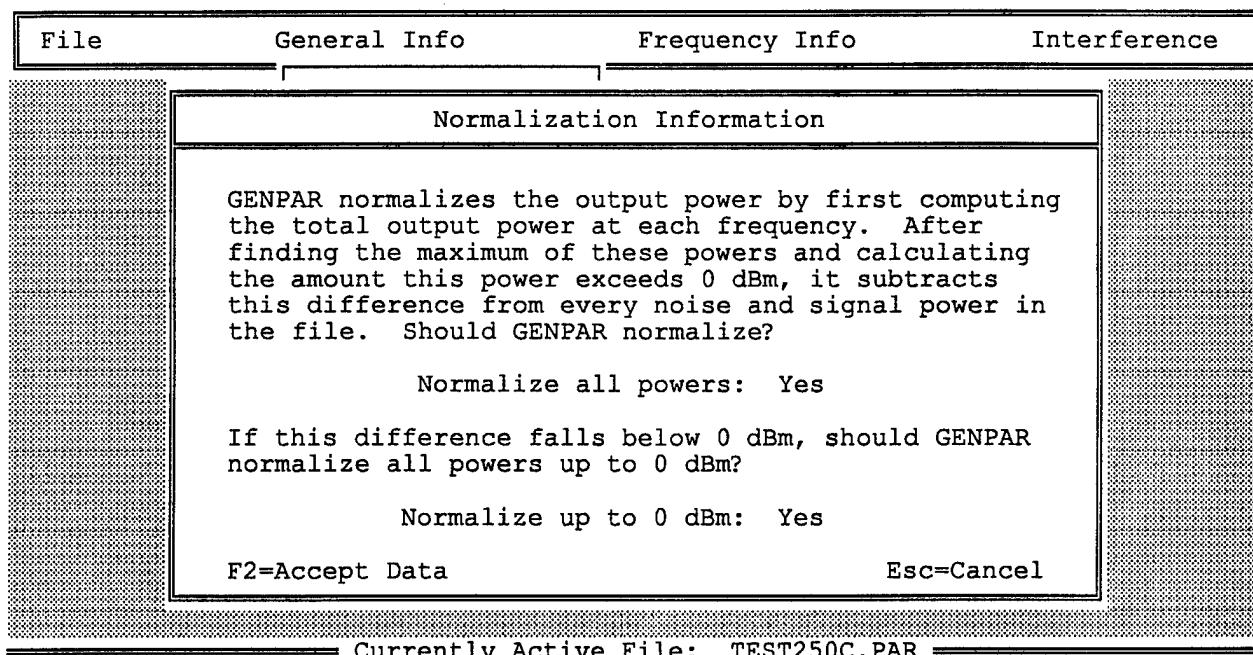


Figure 2.26 Normalize Information Form

2.2.3 Path Parameters Option

The Path Parameters form (Figure 2.27) contains correlation coefficients and path diversities and should be filled out before closing a parameter file. The correlation coefficients characterize the correlation between frequencies for each tap. The default is 1.0, which represents the ideal case of frequency independent multipath.

The path diversity numbers on this form allow assigning each delay tap to diversity 1 or diversity 2. The defaults are 1, for no-diversity simulation.

File	General Info	Frequency Info	Interference																																		
<input type="button" value="Specify..."/>																																					
<table border="1"> <tr> <td colspan="2">Path Parameters</td> </tr> <tr> <td colspan="2">Correlation Coefficients</td> </tr> <tr> <td>Path 1:</td> <td>0.000000</td> <td>Path 4:</td> <td>0.000000</td> </tr> <tr> <td>Path 2:</td> <td>0.000000</td> <td>Path 5:</td> <td>0.000000</td> </tr> <tr> <td>Path 3:</td> <td>0.000000</td> <td>Path 6:</td> <td>0.000000</td> </tr> <tr> <td colspan="2">Diversities</td> </tr> <tr> <td>Path 1:</td> <td>1</td> <td>Path 4:</td> <td>1</td> </tr> <tr> <td>Path 2:</td> <td>1</td> <td>Path 5:</td> <td>1</td> </tr> <tr> <td>Path 3:</td> <td>1</td> <td>Path 6:</td> <td>1</td> </tr> <tr> <td colspan="2">F2=Accept Data</td> <td colspan="2">Esc=Cancel</td> </tr> </table>				Path Parameters		Correlation Coefficients		Path 1:	0.000000	Path 4:	0.000000	Path 2:	0.000000	Path 5:	0.000000	Path 3:	0.000000	Path 6:	0.000000	Diversities		Path 1:	1	Path 4:	1	Path 2:	1	Path 5:	1	Path 3:	1	Path 6:	1	F2=Accept Data		Esc=Cancel	
Path Parameters																																					
Correlation Coefficients																																					
Path 1:	0.000000	Path 4:	0.000000																																		
Path 2:	0.000000	Path 5:	0.000000																																		
Path 3:	0.000000	Path 6:	0.000000																																		
Diversities																																					
Path 1:	1	Path 4:	1																																		
Path 2:	1	Path 5:	1																																		
Path 3:	1	Path 6:	1																																		
F2=Accept Data		Esc=Cancel																																			

Currently Active File: TEST21BB.PAR

Figure 2.27 Path Parameters Form

2.2.4 Forms Defaults Option

This option re-initializes all parameter file form fields with the values stored as defaults in the forms. In other words, selecting this option and then confirming it is equivalent to exiting GENPAR and invoking it again; the values in the field will be the same. The confirmation form displayed for Forms Defaults is shown in Figure 2.28.

2.2.5 Restore Last Save Option

The user can select this option when it is useful to retrieve previous data. GENPAR, after various actions, keeps the current data as its default data and can restore it if needed. GENPAR makes current data its default data whenever a file is read in or after a save to file and at start-up. The same confirmation form (Figure 2.28) is used as for the Forms Defaults option before the restore is implemented.

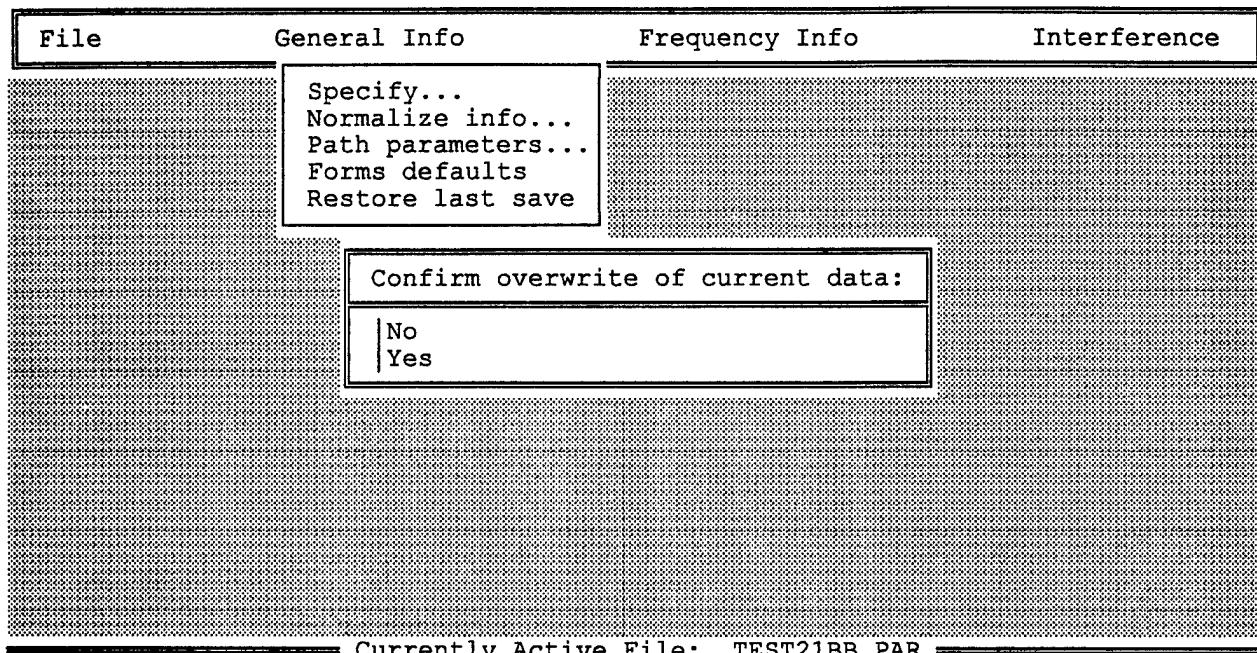


Figure 2.28 Overwrite Confirmation Form

2.3 FREQUENCY INFO WINDOW

The two options in the Frequency Info window (Figure 2.29), Current Page and Select Page, refer to frequency pages. The number of frequency pages entered in the Specify option is the maximum number of frequencies. Also, GENPAR keeps track of the current page number and, if no other page number is specified with the Select Page option and the user selects the Current Page option, that number frequency page will be displayed.

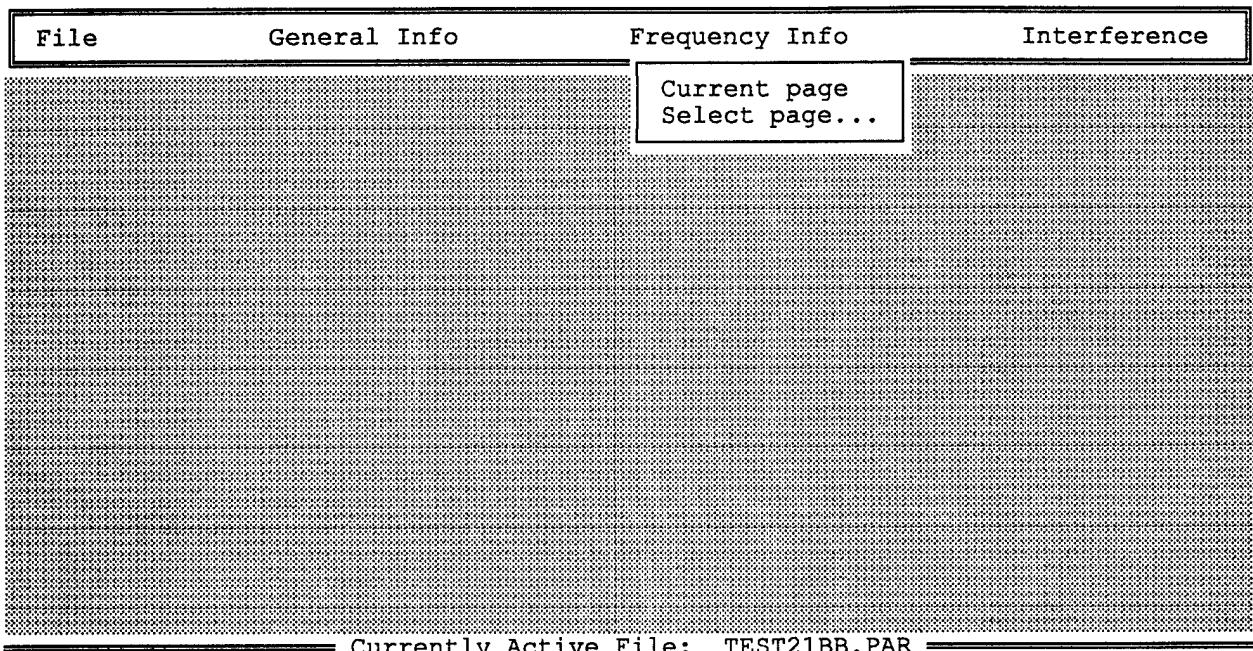


Figure 2.29 Frequency Info Window

2.3.1 Current Page Option

This option causes GENPAR to display the frequency page data corresponding to the current page number (Figure 2.30). GENPAR enters the current page number in the frequency page number field and the corresponding frequency in the simulated frequency field as the form is called up. GENPAR also computes and enters the 80 kHz bandwidth noise power at that time and keeps it updated at 3 dB more than the 40 kHz value whenever the 40 kHz bandwidth noise power field changes. Thus the user does not need to edit the frequency page number field or the 80 kHz bandwidth noise power field, and, in fact, they are not editable.

File	General Info	Frequency Info	Interference
Frequency Page Information			
Frequency Page Number 1 Noise Power in 40 kHz:-200.000000		Simulated Frequency 2.000000 MHz dBm; in 80 kHz:-197.000000 dBm	
	Signal Power (dBm)	Delay (msec)	Doppler Shift (Hertz)
			Doppler Spread (2σ , Hertz)
Path 1:	-8.000000	0.00000	0.000000
Path 2:	-8.000000	2.00000	0.000000
Path 3:	-8.000000	4.00000	0.000000
Path 4:	-8.000000	6.00000	0.000000
Path 5:	-8.000000	8.00000	0.000000
Path 6:	-8.000000	10.0000	0.000000
Noise Power Range: [-200., 0.0]			
F2=Accept Data F8=Normalize Power	F4=Copy Freq Pages F10=Next Freq Page	F6=Select Freq Page	Esc=Cancel

— Currently Active File: TEST21BB.PAR —

Figure 2.30 Frequency Page Information Form

The appropriate valid ranges for the noise powers and for the four types of path data are displayed under the path data table in yellow when any of these fields is selected. In addition, the user will get an error message if an unacceptable value is entered. For instance, the delay is entered as a floating point number that must be in the range of -10.0 to +150.0 msec. Note that since delay resolution is 10 μ sec, only two digits after the decimal point are significant.

An asterisk (*) to the left of one of the signal powers indicates that jamming is in effect on this path and frequency, and that the jammer signal is replacing its signal power. A message to this effect is displayed under the table and before the data range display line. Any jammed signal is not editable, and an error message will be displayed if the user attempts to edit one.

Selecting <F2=Accept Data > is necessary to save each page of data.

Selecting <F4=Copy Freq Pages> causes another form to be displayed which can be used to copy a group of pages to another group of pages (Figure 2.31). The user should enter the first page number of the group of pages to be copied from into the source frequency page number field and the first page number of the group of pages to be copied to into the destination frequency page number.

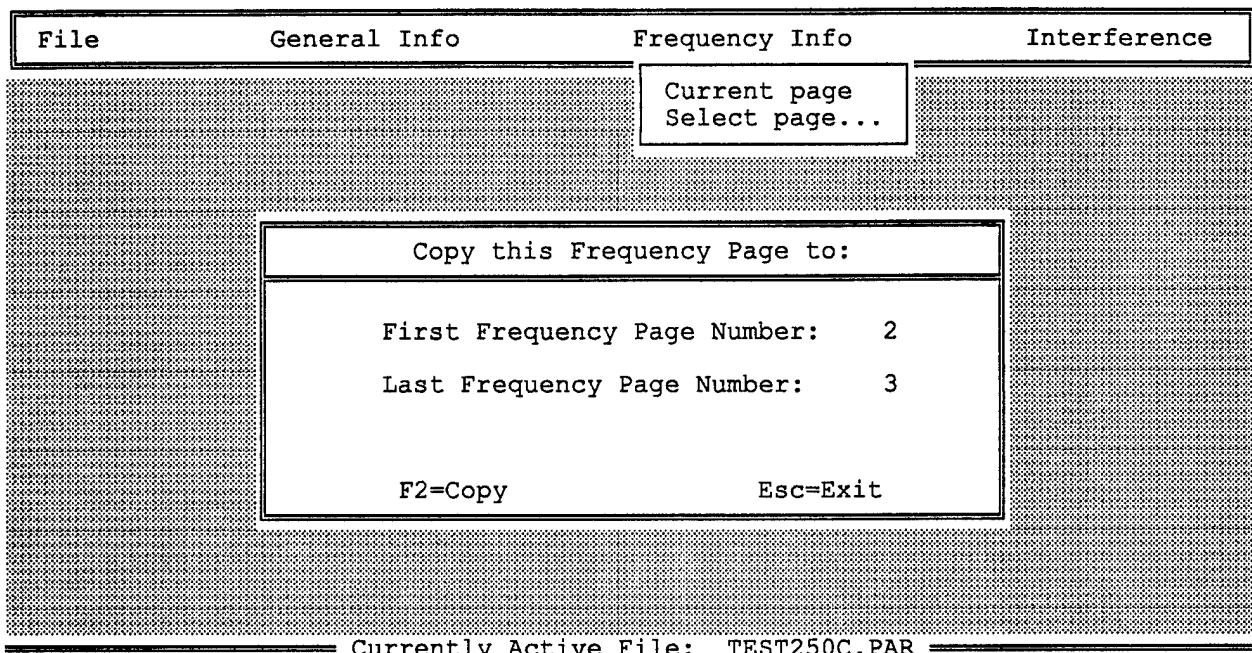


Figure 2.31 Copy Freq Pages Form

Selecting <F6=Select Freq Page> displays the same form as the Select Frequency form (Figure 2.32), described next, and is useful if the user wants to randomly access a page other than the next one. Selecting <F10=Next Freq Page> would be the most convenient action for moving to the next page.

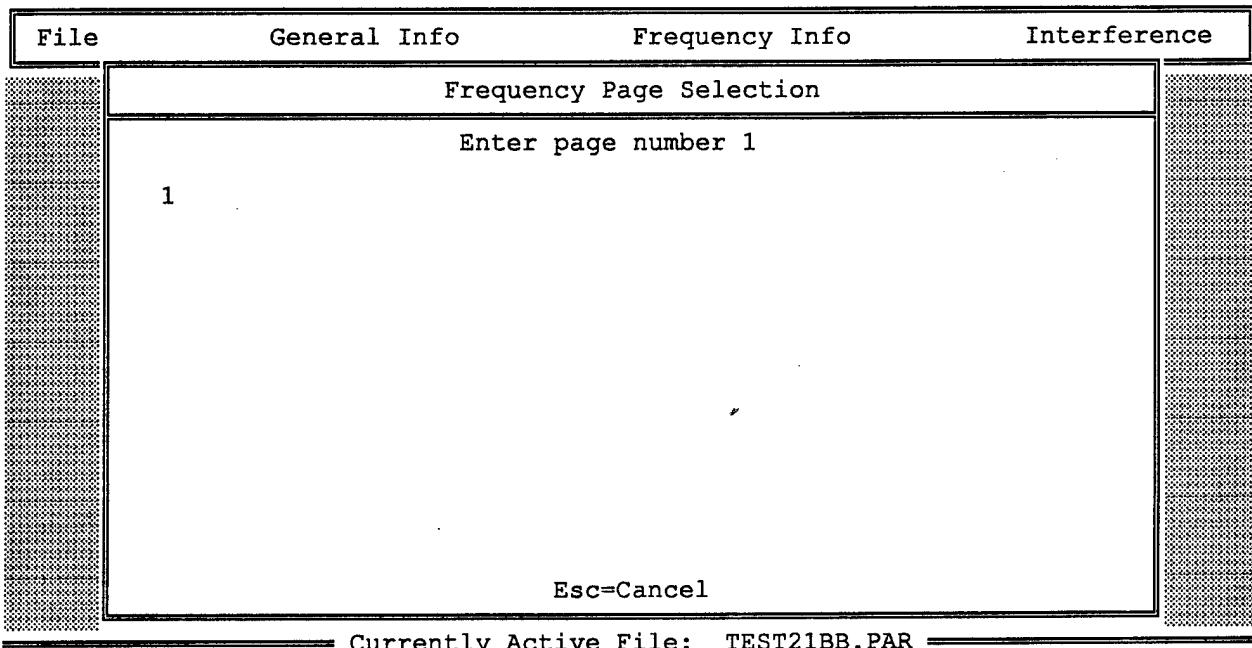


Figure 2.32 Select Frequency Form

If normalization has been turned on in the Normalizing Information form, selecting <F8=Normalize Power> causes all values currently in noise and signal power fields and the various interference amplitudes to be scaled to the largest total power over all frequencies and over all paths. Any change in a power field after normalizing would clearly invalidate the result. Normalization is also (re)performed automatically before data is written out to a file if it has been turned on under the General Info option.

Selecting <F10=Next Freq Page> causes the next frequency page to become the current page and to be displayed. If the next page number exceeds the maximum specified page, GENPAR makes the next page number one and displays frequency page one.

2.3.2 Select Page Option

The user can call up the Frequency Page Selection form (Figure 2.32) for any frequency page at any time by selecting the corresponding page number on this form. Either typing in the desired number followed by <Enter> or clicking on a numbered button will bring up the corresponding frequency page immediately. There is no <F2> action needed on this form, making it the only form which has none.

2.4 INTERFERENCE WINDOW

Several options in the Interference window (Figure 2.33) have a bearing on all signal and noise powers when they are in effect. The first two options will display forms only if a jammer was chosen in General Info's Specify form. The Impulse noise form and the intermodulation Effects form are displayed when selected. Intermodulation interference has no effect on powers unless it is turned on in the Specify form also. On all interference forms, <F2=Accept Data> must be pressed for the user to save the data.

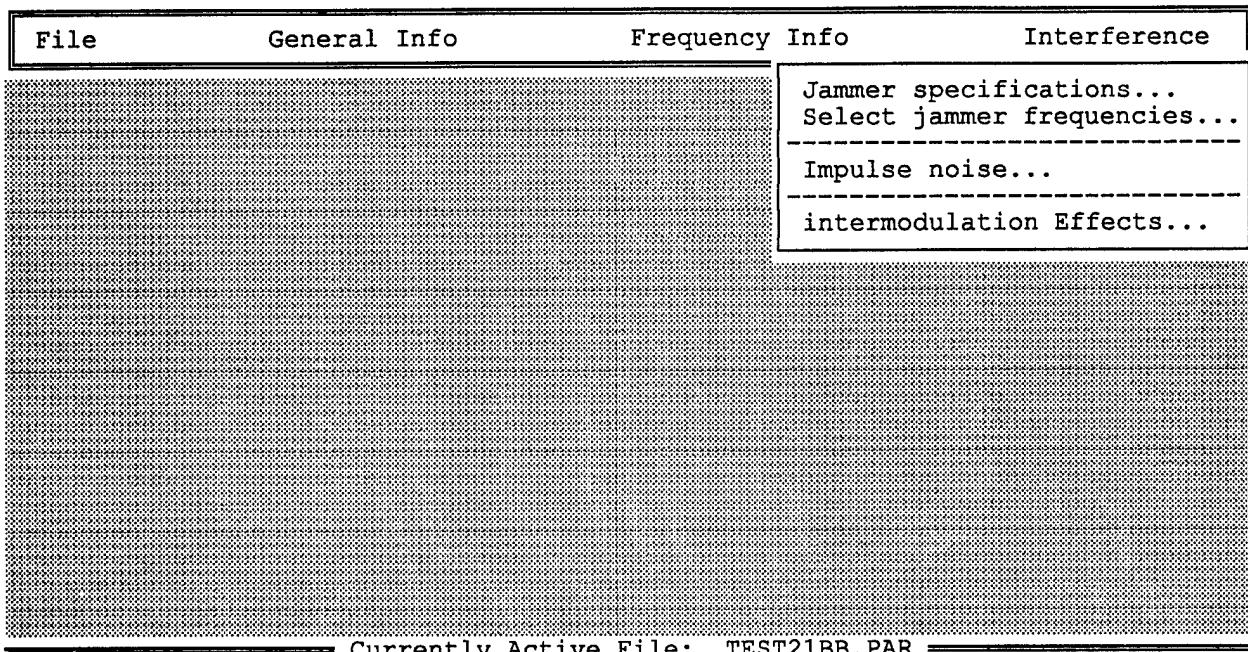
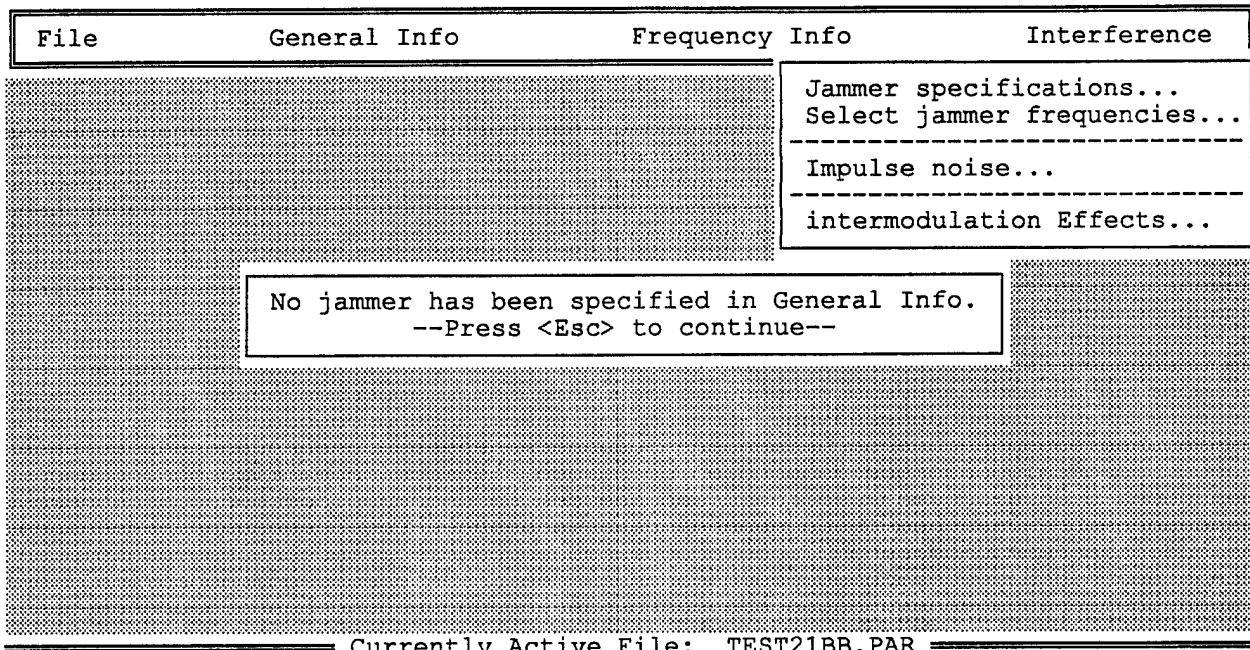


Figure 2.33 Interference Window

2.4.1 Jammer Specifications Option

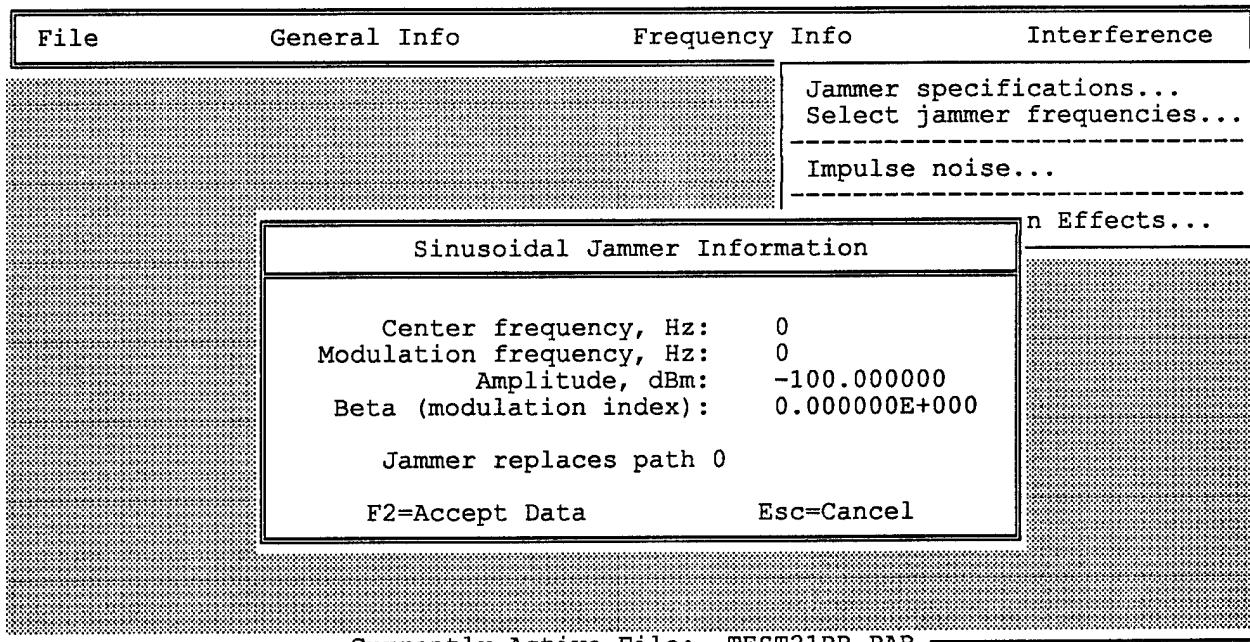
Selecting this option brings up one of three jamming forms, depending upon the jammer type selected in the parameter file information form, or a GENPAR message to the user in the event that no jammer was selected (Figure 2.34). The jammer forms are Sinusoidal Jammer Information (Figure 2.35), Swept FM Jammer Information (Figure 2.36) and Tone Jammer Information (Figure 2.37).

SIGNATRON TECHNOLOGY



Currently Active File: TEST21BB.PAR

Figure 2.34 No Jammer Selected Message



Currently Active File: TEST21BB.PAR

Figure 2.35 Sinusoidal Jammer Information

SIGNATRON TECHNOLOGY

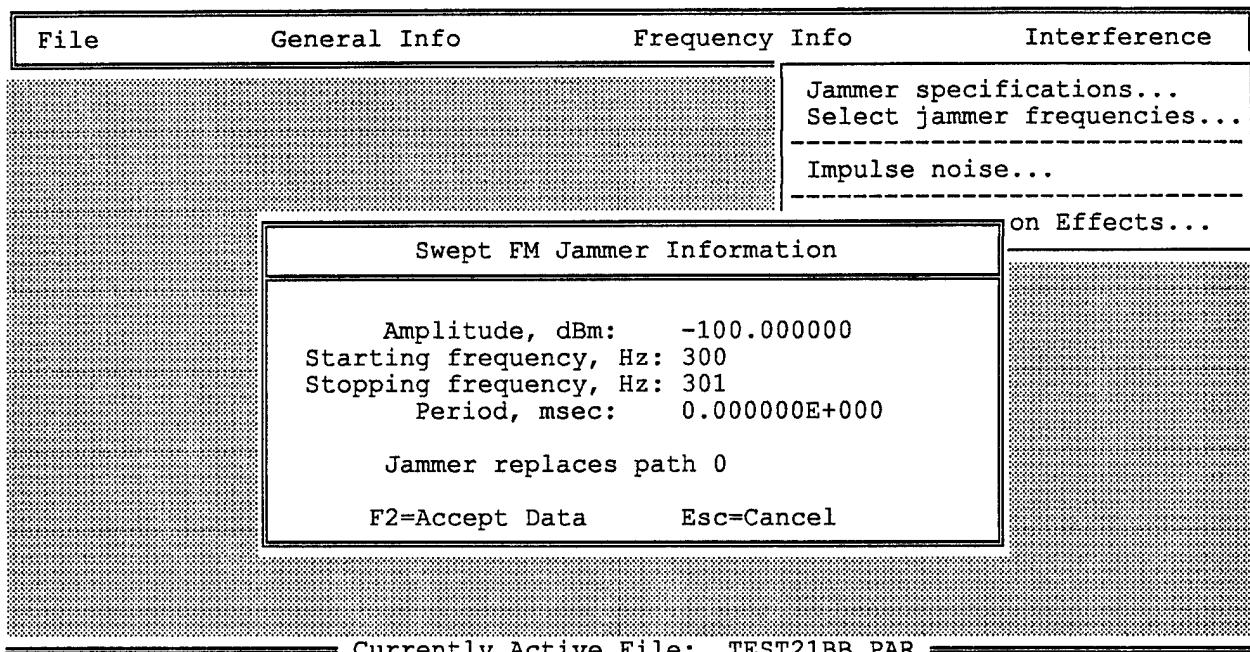


Figure 2.36 Swept FM Jammer Information

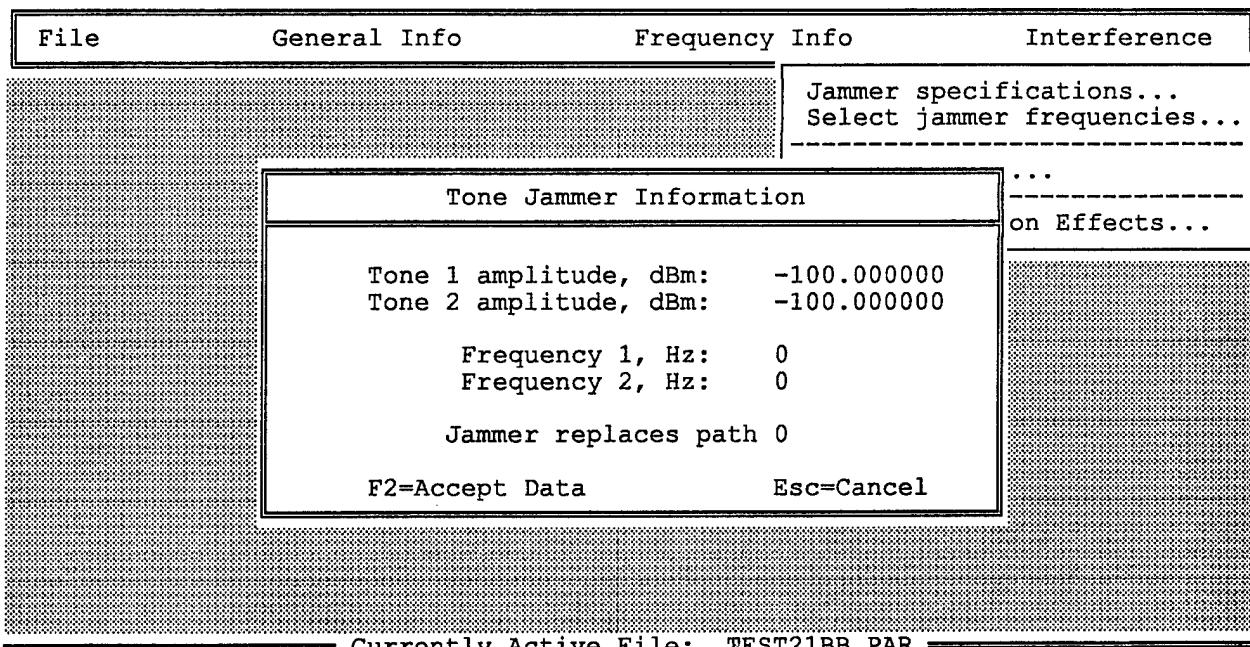


Figure 2.37 Tone Jammer Information

Since all jammers can be path specific, each jammer form has a path number field. This field having the value 0 is equivalent to saying that the jammer is non-fading and therefore does not require the use of a fading tap.

Again all forms have field range validations. The Swept FM jammer form has the added restriction that the stopping frequency has to be strictly greater than the starting frequency and GENPAR checks for that.

2.4.2 Select Jammer Frequencies Option

This option provides the user with a page of valid frequency page numbers from which to choose the jammed frequencies (Figure 2.38). Each frequency is selected by clicking with the mouse or pressing a key OTHER than <Enter> on the keyboard as for any other toggling field. Selection is indicated by a checkmark (✓) to the left of the number (Figure 2.39).

Note that even if a jammer is turned on in the Parameter File Information form, there can only be an effect in normalization if the jammed frequencies are selected also.

File	General Info		Frequency Info		Interference									
Jammer Frequencies Selection														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
F2=Accept Data Esc=Cancel														
————— Currently Active File: 15.GP —————														

Figure 2.38 Select Jammer Frequencies Option

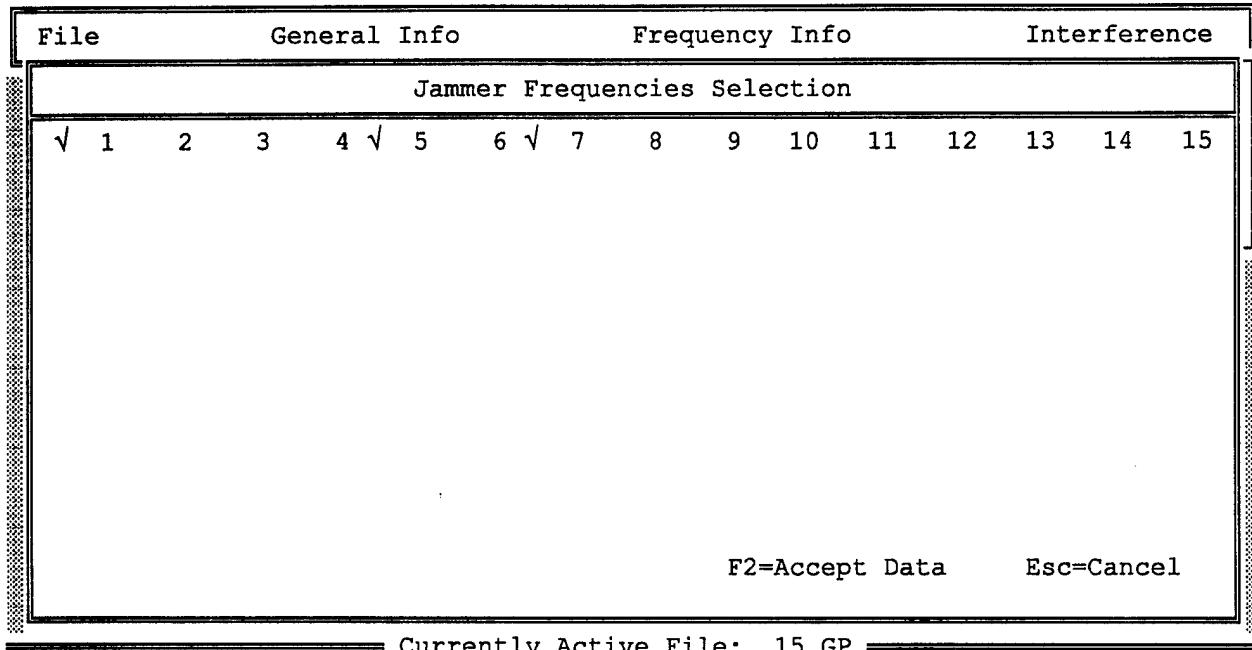


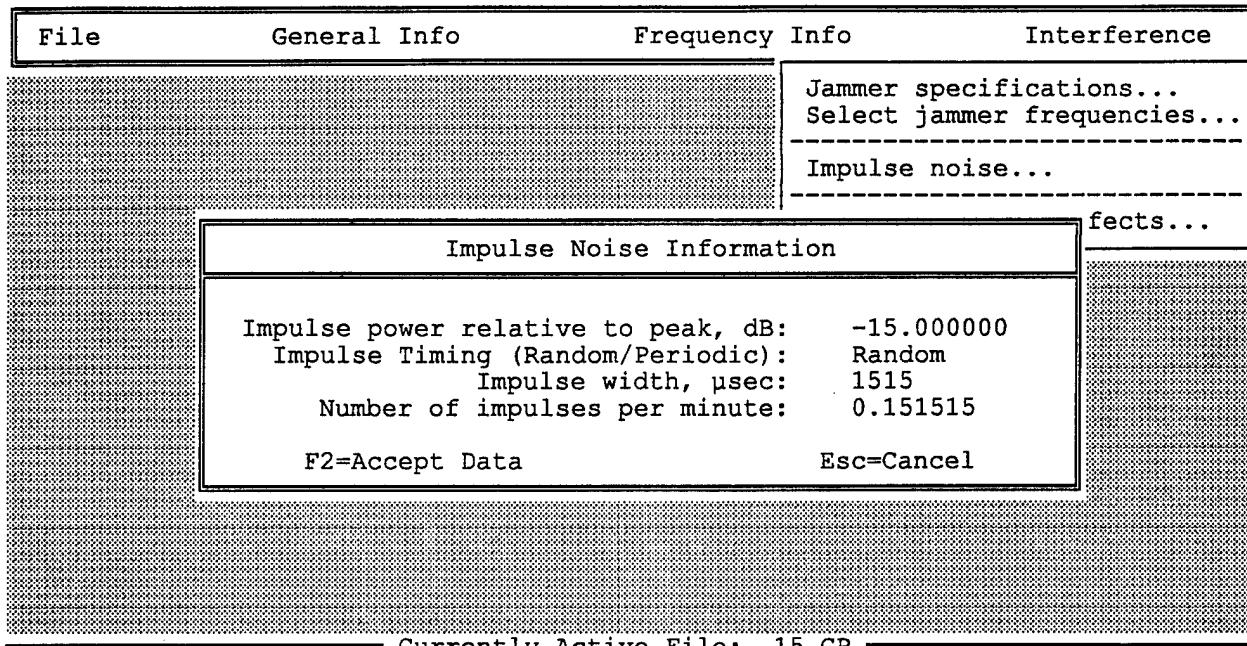
Figure 2.39 Selected Jammer Frequencies

2.4.3 Impulse Noise Option

The Impulse Noise form (Figure 2.40) has beside its usual field range checks a validation of the relationship between the number of pulses per minute and the impulse width in μ sec. When the user presses <F2=Accept Data>, GENPAR checks that

$$\frac{60 \cdot 10^6}{\text{impulse rate[pulses per min]}} \geq \text{impulse width[msec]}$$

The user is alerted if this inequality does not hold and then has the opportunity to change one or both value(s).

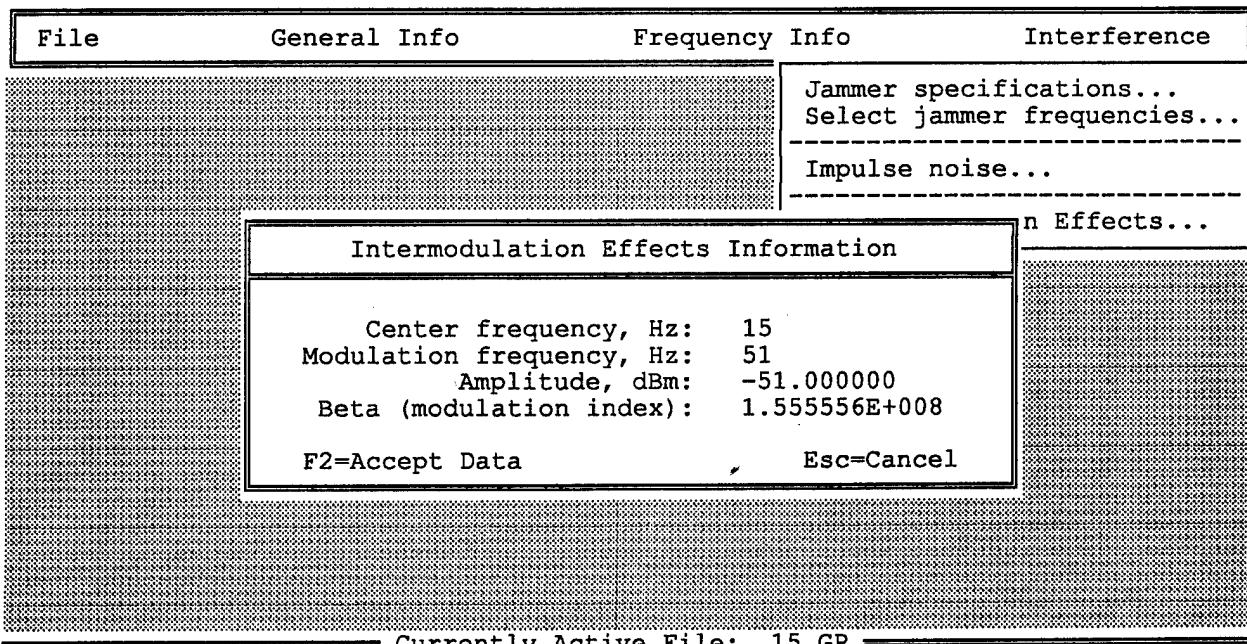


Currently Active File: 15.GP

Figure 2.40 Impulse Noise Option

2.4.4 Intermodulation Effects Option

The Intermodulation Effects Information form (Figure 2.41) has the usual field validations.



Currently Active File: 15.GP

Figure 2.41 Intermodulation Effects Option

SECTION 3

HFSIM AND SIMULATOR OPERATION

3.0 INTRODUCTION

The Program HFSIM controls the operation of the S250C by means of parameter files generated by the GENPAR program described in Section 2. To access the files, HFSIM opens a Master file, which contains a list of parameter files. The user must prepare this file, and the parameter files that are listed in the Master file, prior to running HFSIM. The procedures in the following sections are described using the Master and Parameter files delivered with the simulator. In addition, several procedures are included in the Acceptance Test Report.

When simulating with frequency hopping, it is necessary to adjust the simulation delay of hop components to get the best synchronization with the receiver. Non-hopping simulations will use default path-delay adjustments. In order to provide flexibility, particularly in Hopping Simulations, the user can change the defaults by setting a command line option flag, as described in Section 3.5.

3.1 BASEBAND SIMULATION PROCEDURE

Begin by obtaining a signal source, such as a modem or a low frequency signal generator. The signal must fall with the simulator baseband passband of 300 to 20,000 Hertz.

Set two of the front panel switches (refer to Figures 3.1 and 3.2) as follows:

RF/Baseband to Baseband (Up)

AGC to Off (Down)

If a balanced 600 ohm input is being used, connect it to the 3-pin Amphenol connector on the front panel and set the:

50/600 ohm switch to 600 (Down).

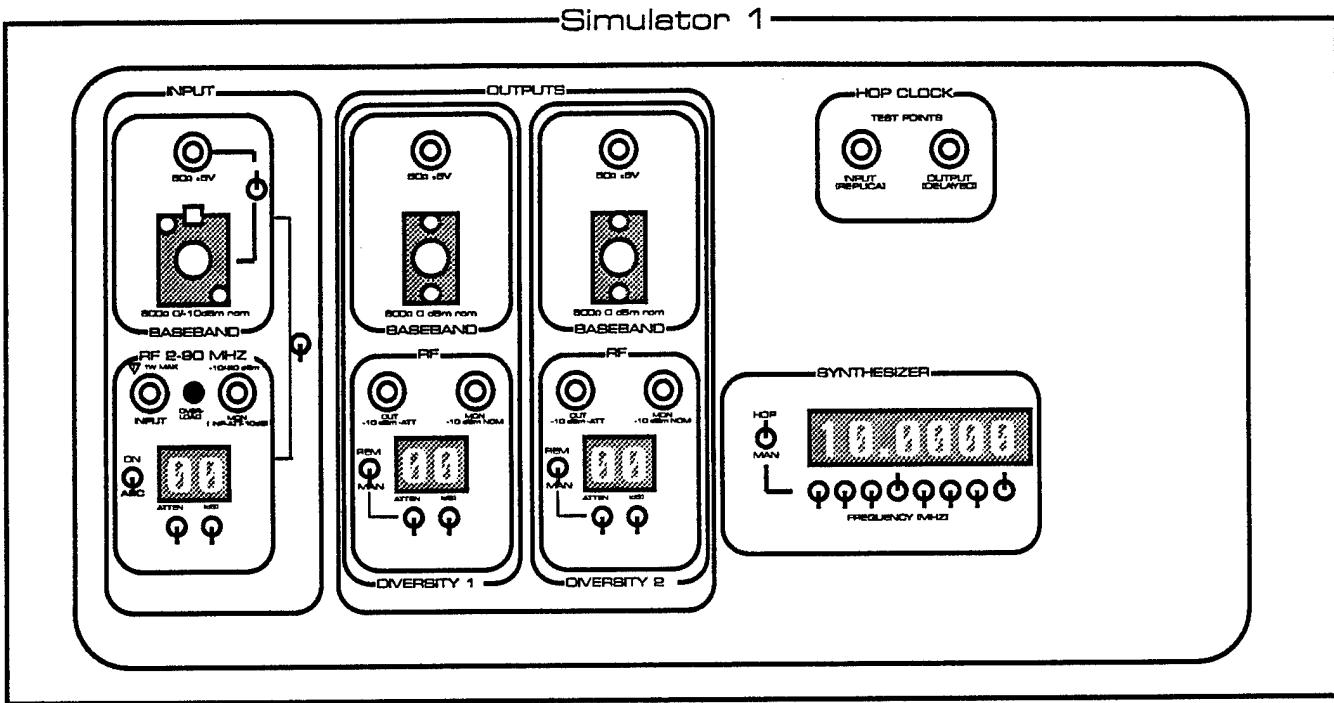


Figure 3.1 S250C Main Front Panel

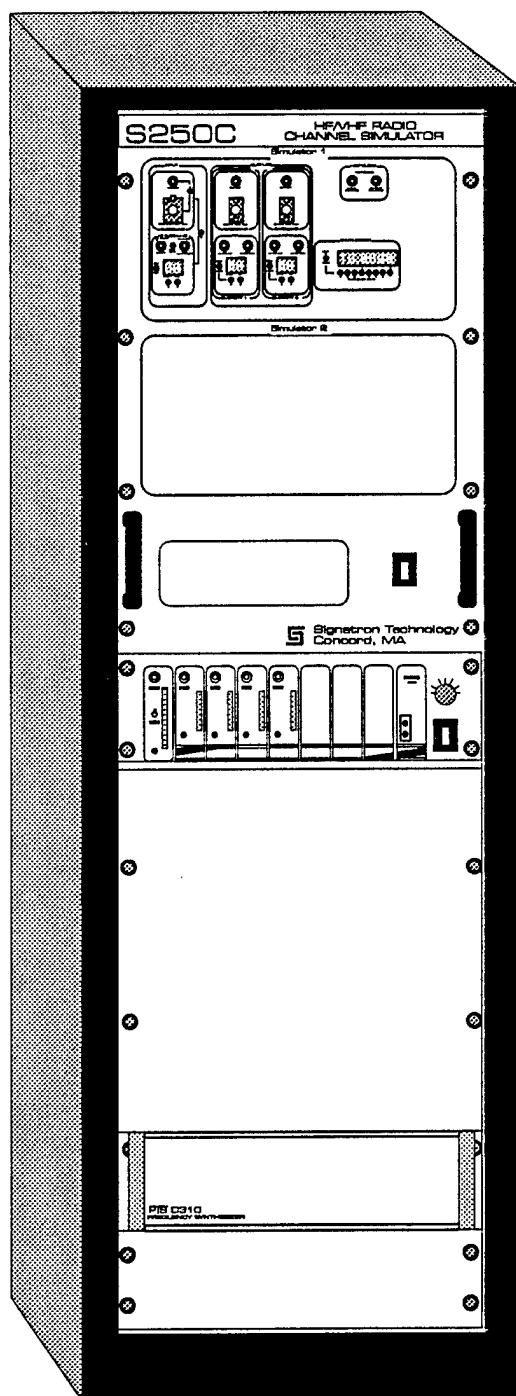


Figure 3.2 S250C Simulator Rack

If a single ended input is being used, set the:

50/600 ohm switch to 50 (Up).

The baseband simulator is calibrated for the 600 ohm baseband input. Set this level to approximately 0 dBm, or about 2 volts peak-peak. If it is inconvenient to set the level, connect it to the simulator and allow the simulator to measure the level in the following steps.

If using the 50 ohm input, set it to about 5 volts peak-peak. This is a test-only input, and is available for convenience. Setting the test input to this level tricks the simulator into thinking a 0 dBm, 600 ohm balanced input is present.

Now type the following at the DOS prompt on the PC:

>HFSIM bb_demo.mst

HFSIM starts to run by opening the first parameter file and checking whether it is a baseband or RF simulation. It then verifies that all files are of the same type. It also verifies that all files have been normalized. If some RF files are mixed in, or some files have not been normalized, HFSIM alerts the user and exits.

If the files checks are successful, HFSIM displays:

```
----- Signatron S250C HF/VHF Channel Simulator -----
Verifying contents of Master File bb_demo.mst
Parameter file #1: bb_clear.par                               GOOD
Parameter file #2: bb_fade.par                               GOOD
Radio must be connected at Baseband
There will be 2 simulations for a total of 2 hrs 0 mins
Do you wish to continue ?
```

The simulator prints the input level. If the input level is between 0 and -6 dBm, HFSIM opens the first parameter file and the simulation begins. If the input level is outside of this range, a dialog ensues which gives the user an opportunity to adjust the level and measure again. If the input level is outside the 0 to -6 dBm range, an option to proceed without remeasuring is offered to the user. Under the

circumstances described in Section 3.6, the user may want to intentionally set the input outside the 0 to -6 dBm range. The measurement dialog is given below:

Signatron S250C HF/VHF Channel Simulator

The simulator will now measure the input signal level.

Enter measured dBm => -2.0

The simulator then opens the first parameter file, which is **bb_clear.par**. This file turns on one path, which is set to a Doppler spread of zero (non-fading) with no Doppler shift, and a delay of zero.

Selected parts of the parameter file are then displayed on the screen.

Once the parameter file is read into its memory, the simulator calculates each path's average Doppler spread. This average value is what the simulator uses as a fade rate for a given path at all frequencies. Thus, there are really six distinct fade rates simulated rather than 768 (6 paths x 128 frequencies); to simulate all 768 fade rates in real-time would require computational power that is not presently available. Each frequency, however, does fade independently (although at the same rate). The simulator prints the results of its calculations:

Signatron S250C HF/VHF Channel Simulator

Parameter File : TEST52BB.PAR

1 Frequency: 2.000 MHz

Path #	Averaged Over ALL Frequencies		
	Signal Power (dBm)	2 sigma	Doppler Spread (Hz)
1	-4.80		10.00
2	-4.80		5.00
3	-4.80		2.50
4	-200.00		0.00
5	-200.00		0.00
6	-200.00		0.00

To STOP this simulation early:
press the 'N' key to proceed to the Next parameter file,
press the 'S' key to Stop all simulations,
press the 'Q' key to Quit program (let Simulator run).

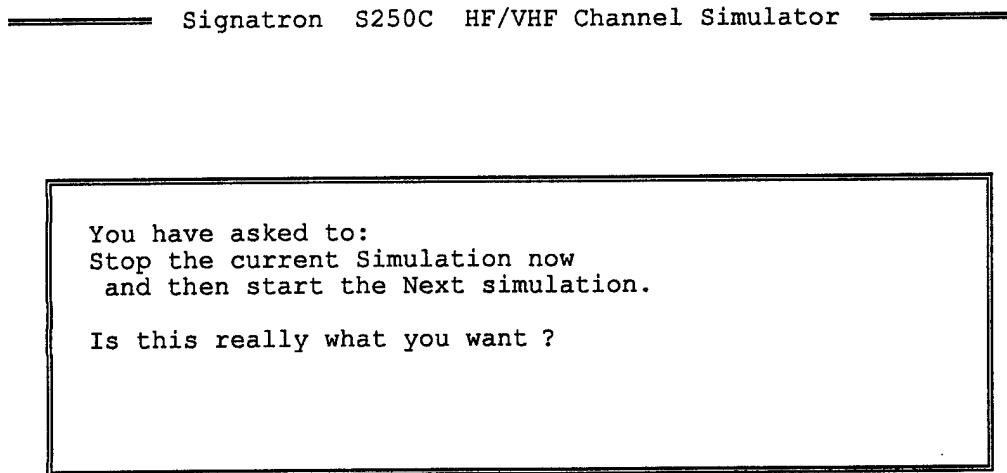
This simulation started at: Fri May 24 13:16:15 1996
The Scheduled end time is: Fri May 24 14:16:15 1996

Here path 2 is shown to average to less than 0.02 Hz, the minimum allowable fade rate. The simulator uses a value of 0.02 Hz in this case.

Now view the Diversity 1 output on an oscilloscope, signal analyzer or spectrum analyzer. Either the 50 ohm or 600 ohm baseband outputs can be used. The input and output should be identical except for a delay of 5 milliseconds (this is a result of the delay defaults described in Section 3.5).

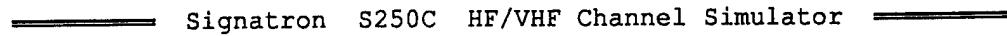
When ready, press the N (for next) key to access the next parameter files, **bb_fade.par**, which causes one tap to fade with a Doppler spread of 1 Hertz. The tap will fluctuate and the tap weight spectrum can be viewed on a signal analyzer if desired. This procedure is included in Test 5 of the Acceptance Test Report.

Press N to move on to file **bb_dop.par**. The following dialog appears:



This file turns fading off, but puts a Doppler shift of 100 Hertz on the signal. View this on the test instrument. Now turn the AGC switch to ON (Up) and adjust the input level a few decibels in either direction. Verify that the AGC adjusts for changes in the input signal.

When you request to stop the simulation, you get the following dialog:



You have asked to:
Stop the current Simulation now
and then terminate the control program.
Is this really what you want ?

3.2 RF SIMULATION (NON-HOPPING)

Begin by obtaining a signal source or RF Transmitter. If a high power source is being used, insert appropriate attenuators between the transmitter and the simulator. The maximum power to the simulator is 1 Watt.

Set the front panel switches (see Figures 3.1 and 3.2) as follows:

RF/Baseband to RF (Down)

AGC to OFF (Down)

Synthesizer Control to Manual (Down)

An input attenuator is built into the simulator. This attenuator can be set to 0 to 29 dB. An input monitor is also provided which is **10 dB below** the level the simulator sees. This point can be attached to a power meter to simplify setting the input level. If this connection is not in use, terminate it in 50 ohms.

Verify that the input signal is in the simulator RF passband. This is set by means of the manual synthesizer control. If the display is set to 10 MHz, the simulator passband is from 9.960 to 10.040 MHz. Set the center of the simulator passband using the switches under the display.

Now type the following at the DOS prompt on the PC:

>HFSIM rf_demo.mst

HFSIM starts to run by opening the first parameter file and checking whether it is a baseband or RF simulation. It then verifies that all files are of the same type. It also verifies that all files have been normalized. If some baseband files are mixed in, or some files are not normalized, HFSIM alerts the user and exits.

If the file checks are successful, HFSIM displays:

This is an RF simulation. The simulator will now measure the input level.

The simulator does this, then prints the input level. If the input level is between 0 and -6 dBm, HFSIM opens the first parameter file and the simulation begins. If the input level is outside of this range, a dialog ensues which gives the user an opportunity to adjust the level and measure again. If the input level is outside the 0 to -6 dBm range, an option to proceed without remeasuring is offered to the user. Under the circumstances described in Section 3.6, the user may want to intentionally set the input outside the 0 to -6 dBm range.

The simulator then opens the first parameter file, which is **rf_clear.par**. This file turns on one path, which is set to a Doppler Spread of zero (non-fading) with no Doppler shift, and a GENPAR Delay of zero.

Selected parts of the parameter file are displayed on the screen.

Now connect the Diversity 1 Output to an oscilloscope or spectrum analyzer. Set the RF Output Attenuator to 0 dB. If an oscilloscope is used, provide a 50 ohm termination. The RF output monitor, which provides the same level as the Diversity output when the RF attenuator is set to zero, can also be used. Terminate the unused output in 50 ohms.

The input and output should be identical except for a delay of 5 milliseconds (this is a result of the delay defaults described in Section 3.5). At high frequencies, this delay will be difficult to observe, so a pulsed source can be used at this point.

When ready, press the N (for next) key to access the next parameter file, **rf_fade.par**, which causes one tap to fade with a Doppler spread of 1 Hertz.

Now access the next file, **rf_dop.par** which turns fading off, but puts a Doppler shift of 100 Hertz on the signal. Now turn the AGC switch to ON (Up) and adjust

the input level a few decibels in either direction. Verify that the AGC tracks the changes in the input signal.

3.3 HOPPING SIMULATIONS

Frequency Hopping Simulation requires an external source of frequency and time-of-frequency-change control for the S250C. This is provided by an adapter/translator which usually consists of a connection to the transmit radio under test.

3.3.1 RF Hopping Simulation

The procedure for setting up an RF hopping simulation consists of making the connection to the adapters, and connecting the radio (through suitable attenuators) to the S250C. Set the Synthesizer Control Switch to HOP (Up). Run the transmit radio briefly and verify that the hop information is appearing on the display.

Set the approximate RF level while the unit is hopping, using the method described in the previous section.

Start the simulation as before, using a Master file that contains parameter files with multiple (up to 128) frequency pages which span the anticipated range of hopping.

In this mode, the simulator provides checks on the frequency information received from the external source.. HFSIM reports two errors:

'Hop out of bounds' and

'maximum hop rate exceeded'

3.3.2 Baseband Hopping Simulations

A baseband hopping simulation requires the equivalent of a translator input to control hopping to various pages (frequencies). While the baseband signal will not hop, the channel distortion will change with every hop. Typically, the baseband modem would control the time of hopping to correspond to output bursts.

3.4 DUAL DIVERSITY OPERATION

Use GENPAR to create files which assign paths to the second diversity, as described in Section 2, then repeat any of the procedures above.

3.5 DELAY AND ALIGNMENT NON-DEFAULTS

Non-default delays are enabled with the command line option:

hfsim mytests.mst /nd

After a successful measurement, HFSIM will print:

"delay defaults are:

"earliest path is set to 5 mSec.

"receiver timing (upconversion synthesizer) is aligned to the weighted-average
delay of the weighted average strongest paths

These are the delay and alignment defaults. The shortest delay is set to the minimum delay the simulator can physically provide: 5 mSec. In some case, it may be useful to be able to increase the delays. The next prompt provides an opportunity for the user to do so.

"delay: enter the amount by which to increase all delays in milliseconds:__

The alignment default is important only in RF frequency hopping model, since it controls the time at which the up-conversion synthesizer switches, and which paths are early, late, or aligned with this switching.

HFSIM then recalculates all paths and prints:

"earliest path is XXXX mSec

"strongest single path YYYY mSec

"latest path ZZZZ mSec

"weighted average delay aaaaa mSec.

The next prompt gives the user and opportunity to set the alignment:

"Receiver timing: align receiver (upconversion synthesizer) with
Earliest/Biggest/Latest

E/B/L path or enter delay in milliseconds (> 5):__

3.6 INPUT RANGE

The input range of the S250C is set so that a 0 dBm input tone (at RF or baseband) will have a value of half of the A/D input full scale range. The user can therefore drive the input at up to +6 dBm without clipping.

The reason for the extra range or headroom is to allow for a change in signal level during a test, or to accommodate waveforms that do not have a constant amplitude. An example of the former is a transmitter (connected through appropriate attenuators!) whose output power fluctuates when keyed down for long periods of time. Examples of the latter are parallel-tone modems, or hopping radios whose output shaping filter rings a bit during the start of a transmission.

3.7 AGC

In order to test a transmitter as described above, or to maintain calibration over very long tests, the simulator includes an AGC which adjusts the A/D samples so that a 0 dBm signal is returned to the hardware multiplies the signal by the taps weights. By adjusting the signal level in the AGC, no adjustment of path gains, noise or jammer power is necessary.

If the AGC is turned off, the simulator calculates the adjustment factor once, during the measurement phase, but then allows the signal amplitude to drift.

Note that since the level adjustment is after the A/D, it is necessary to ensure that, for example, if the simulation starts with an input level of +2 dBm, it not be allowed to drift more the 4 dB higher, or clipping will result.

SECTION 4
HFPRED**4.0 BRIEF DESCRIPTION**

HFPRED, version 1.3, is a high frequency (HF) propagation prediction program developed at Signatron, Inc. Given the geographical coordinates (longitude West and latitude) or the path length and various other link data (see Section 4.5), the program predicts the received signal level (RSL), signal-to-noise ratio (SNR) and other parameters of interest (see Section 2) as a function of operating frequency within the 2 to 30 MHz band.

The HF propagation prediction calculations performed by HFPRED can be grouped as follows:

- a) Prediction of ionospheric parameters such as the number of reflecting layers, heights of the layers above the surface of the earth and the critical frequencies of the reflecting layers. For a description of these calculations see the first document referenced in Section 4.2.
- b) Prediction of the number of skywave paths and their signal strength and the groundwave signal strength. For a description of these calculations see the second document referenced in Section 4.2.
- c) Prediction of atmospheric and man-made noise levels. For a description of these calculations see the third, fourth and fifth documents referenced in Section 4.2.

4.1 REFERENCE DOCUMENTS

- a) A. Málaga, "A Global Model for Wideband HF Skywave Propagation" in Effect of the Ionosphere on Radiowave Systems, Ed. by J.M. Goodman, based on Ionospheric Effects Symposium, Alexandria VA, April 14-16, 1981, U.S. Government Printing Office.
- b) A. Málaga, "A Characterization and Prediction of Wideband HF Skywave Propagation", MILCOM '85 Conference record, pp. 281-288.
- c) A. Barghausen, et al., "Predicting Long Term Operational Parameters of HF Skywave Telecommunications Systems", ESSA Technical Report ERL-ITS-78, May, 1969.
- d) J.L. Lloyd, et al., "Estimating the Performance of Telecommunication Systems Using the Ionospheric Transmission Channel, NTIA/ITS Report, 1983, pp. 83-127.

- e) CCIR Report 322, "World Distribution and Characteristics of Atmospheric Radio Noise", in documents of the X'th Plenary Assembly, Geneva, 1963.

4.2 PROGRAM LIMITATIONS

Version 1.3 of the HFPRED computer program is limited in the following way:

Simple antennas such as quarter-wave monopoles or half-wave dipoles with a lossless impedance matching network are assumed.

4.3 HFPRED OPERATION

HFPRED has two selectable modes of operations for input and two for output. The user is always asked to choose one of each of these modes at the beginning of program execution. To run HFPRED, type the command:

>HFPRED <Enter>

and answer the questions.

4.3.1 System Requirements (HFPRED)

HFPRED requires a system with at least an 80386 CPU and 80387 numeric coprocessor. These are then the minimum system requirements.

4.3.2 Input

The user is asked to select the manner of input, which may be either by disk file or by responding on-line to program prompts for input parameters on the user's terminal. The user is strongly urged to use the input file method since the on-line method not only requires experience with HFPRED, but is also prone to error. This, of course, means that the input file needs to have been changed with a text editor before the program is run (sample input files labeled [*name*].inp are provided as templates). For a sample input file, see Section 2.

4.3.3 Output

The user is next asked to select the method of output for the complete program output - either to a disk file or to the user's terminal. Lastly, the program prompts for the GENPAR file name which is always written to disk. See Section 2 for sample output files and Section 3 for a discussion of output data items.

4.4 INPUT PARAMETER RANGES

The input file (see sample on page 4-7) consists of 24 input lines where the following data is specified.

- LINE 1: Enter 1 when the geographic location (longitude and latitude) of the Tx and Rx are known. Enter 0 when only the distance between Tx and Rx and the approximate longitude and latitude at mid-path are known.
- LINE 2: Enter the longitude West of Greenwich (0° to 360°) followed by the latitude (-90° to $+90^\circ$, North positive) of the Tx site. When the input to LINE 1 is 0, enter any two values which will be read but ignored by HFPRED.
- LINE 3: Enter the longitude West of Greenwich (0° to 360°) followed by the latitude (-90° to $+90^\circ$) of the Rx site. When the input to LINE 1 is 0, enter any two values which will be read but ignored by HFPRED.
- LINE 4: Enter the approximate longitude West of Greenwich (0° to 360°) followed by the latitude (-90° to $+90^\circ$) at mid-path. When the input to LINE 1 is 1, enter any two values which will be read but ignored.
- LINE 5: Enter the path length (Tx-Rx distance) in km. This is used only when LINE 1 is 0, otherwise, it is ignored. The distance should lie between 20 km and 6000 km.
- LINE 6: Enter the minimum, the maximum and the increment in operating frequency in MHz for which predictions are desired. The minimum frequency should be greater than 2 MHz. The maximum frequency should be less than 30 MHz. The increments in frequency should not be smaller than 0.5 MHz.
- LINE 7: Enter the local standard (not daylight savings) time at the Rx site in decimal hours (0.0 to 24.0).
- LINE 8: Enter the month for which predictions are wanted (integer from 1 to 12).
- LINE 9: Enter the sunspot number (integer from 0 to 150). It is a measure of solar activity.

LINE 10: Enter the planetary magnetic index K_p (integer from 0 to 6). A number close to 0 indicates low to normal auroral activity. A number greater than 4 indicates a highly disturbed aurora visible in the continental USA.

LINE 11: Enter 0, 1 or 2 to select the path loss model desired. The model that is most widely used is the IONCAP mode. (enter 2). The George & Bradley model (enter 1) reflects more accurately absorption phenomena in the ionosphere. The HFMUFES model (enter 0) is the old model superseded by IONCAP.

LINE 12: Enter the choice for the atmospheric noise figure; 0 means use that of the continental United States and 1 means use the user-input noise figure of LINE 13.

LINE 13: Enter atmospheric noise figure (dB above kT) at 1 MHz for receive location and time of interest. NOTE: This data can be obtained from Reference e), Section 4.2. Enter the noise figure if LINE 12 is 1, otherwise, the entry in LINE 13 will be read but ignored.

LINE 14: Enter 0 if the path is closer to North-South propagation, or 1 if it is closer to East-West propagation.

LINE 15: Enter the effective radiated power in watts.

LINE 16: Enter the Tx antenna polarization. 0 = vertical, 1 = horizontal.

LINE 17: Same as LINE 16 but for the Rx antenna.

LINE 18: Enter the elevation pattern for the Tx antenna:

0 = omnidirectional, no ground reflections

1 = quarter wave, vertical monopole if LINE 16 = 0, horizontal loop if LINE 16 = 1

2 = half-wave dipole if LINE 16 = 1, vertical loop if LINE 16 = 0.

LINE 19: Same as LINE 18 but for the Rx antenna.

LINE 20: Enter the data (information) rate in bits/sec followed by the receiver bandwidth (or signaling rate) in Hz.

LINE 21: Enter the noise environment at the Rx site. 1 = rural, 2 = suburban, 3 = urban.

LINE 22: Enter the ground dielectric constant. Values between 4 and 10 should be entered for typical soil. A value of 80 is more applicable for groundwave propagation over sea water.

LINE 23: Enter the ground or earth surface conductivity in mhos/meter. A value of 0.001 or less applies when the ground is poorly conducting such as ice or rock. A value of 0.01 to 0.1 applies to soil with high water content such as agricultural land. A value of 4 applies for groundwave propagation over sea water.

LINE 24: Enter 1 to include a groundwave calculation, 0 to omit it. Note that a groundwave calculation is applicable when the Tx to Rx separation is less than 300 km, propagation is over sea water and vertically polarized avenues are used. When propagation is over land, a groundwave calculation should be included if the Tx to Rx separation is less than 100 km, and vertical polarization is used.

Note that the exact number of data items must be entered on each line of the input file whether they are to be used or not. Failure to comply with this will result in either erroneous answers or abnormal termination of HFPRED.

Note also that HFPRED does not always check for the validity of the input data provided. Hence, data which falls outside the accepted range will not necessarily result in abnormal termination of the execution of the program. However, the results will most certainly not be correct.

SECTION 5

THEORY OF OPERATION

5.0 OVERVIEW

This section summarizes the implementation details needed to make the best use of the Model S250C HF/VHF simulator. Additional details can be found in the separate Software Theory of Operation Manual and in the Hardware Description and Maintenance Manual.

The channel simulation and the interference simulation is implemented digitally and the major characteristics of this is described in the following order:

- 1) Input/Output characteristics, including RF and baseband differences;
- 2) Tapped delay line implementation of the HF channel;
- 3) Tap weight generation, including Doppler shift and the interpolation method used to assure smooth channel fading;
- 4) Frequency hop control;
- 5) Frequency hop correlation;
- 6) Additive Gaussian noise implementation;
- 7) Impulse noise implementation;
- 8) Jamming implementation with several jammer types: Noise Jammer, Tone Jammer, Swept FM Jammer, and Sinusoidal Jammer;
- 9) Intermodulation Interference implementation.

5.1 INPUT/OUTPUT CHARACTERISTICS

The input signal for the simulator can be either a baseband signal outputted from a modem or an RF signal outputted by a radio in the 2-90 MHz band. The RF signals may be at a fixed frequency or may be hopping at up to 1000 hops per second. Regardless of the source of the signal, the tapped delay line implementation of the channel requires a digitized complex baseband signal. The real-to-complex transformation is performed by a hardware Hilbert transformation for the baseband signal and by a quadrature demodulation to baseband for the RF signal.

In the RF case the signal is converted to a low IF and sampled as a complex signal at a rate of 100 kHz. This sample rate allows accurate channel simulation over a 80 kHz bandwidth. The input level should be in the range of -10 dBm to 30 dBm (1W) maximum). An input attenuator can adjust the transmitted signal to a nominal level (0 to -6 dBm) and an Automatic Gain Control (AGC) is used to keep the Signal-to-Noise ratio (SNR) constant during a simulation, even when the transmitter power level drifts. The AGC is also set to make best use of the A/D converters dynamic range. At the output the signal is converted to analog on two diversity outputs. Each diversity receives a fading signal from a different subset of taps and different additive noise. However, impulse noise and jamming is the same on both diversity outputs. Diversity is only enabled in the non-hopping mode.

In the baseband case a 300 Hz to 20 kHz signal on the 600 Ohm input is sampled at 100 kHz and converted to a complex signal with a Hilbert Transform filter. This filter reduces the negative frequencies to a level of better than 50 dB below the corresponding positive frequency. A bandpass filter is used at the output to filter the real part of the complex signal from the simulator. Two diversity outputs are available as above, except when frequency hopping is simulated.

The "S250C HF Simulator Hardware Description and Maintenance Manual, Volume I" describes the input/output process in more detail.

5.2 TAPPED DELAY LINE IMPLEMENTATION

The channel multipath is implemented as a tapped delay line, with each multipath component represent by a tap. This is implemented digitally with 100 kHz signal samples which are stored in digital memory and weighted using 16 bit fixed point arithmetic. A total of 6 taps are available and each path (or tap) can be delayed up to 160 msec. The tap weights used are calculated on the DSP board. In frequency hopping mode the weights are changed with the frequency.

Each path simulates an independently fading signal at an arbitrary time delay. Each is multiplied by an independent Rayleigh process and Doppler shifted by an independent single-sideband shift. The processes are added together, along with the impulse and Gaussian noise, to form the output signal.

Dual diversity processing is slightly different. Instead of summing all six processes together, they are summed in two groups, with each group representing an

independent diversity channel. Independent Gaussian noise and identical impulse noise signals are added to these to simulate two diversity output signals. The allocation of the six paths between the two diversities is under the operator's control.

5.3 TAP WEIGHT GENERATION

The fading tap weights are generated in the DSP every 10.0 msec as complex samples in 32 bit floating point format. These samples are converted from real and imaginary to polar (amplitude, phase) in 16 bit fixed point format. Linear interpolation between successive 16 bit samples is then used to generate the tap weights at the signal sample rate of 100 kHz. Doppler shift is added before multiplication with the signal samples.

The 10 msec tap weights are generated in software from independent Gaussian complex random values which are then filtered by a 3-pole digital Butterworth filter. Since the input to the Butterworth filter are uncorrelated Gaussian complex values, the low-pass filtered output is then Rayleigh fading at a rate controlled by the filter bandwidth, and with the power spectrum:

$$|H(f)|^2 = \frac{1}{1 + \left[\frac{\tan(\pi f T)}{\tan(\pi B T / \sqrt{2})} \right]^6}, \quad -\frac{1}{2T} < f < \frac{1}{2T}$$

where T is the weight sample period of 10 msec and B is the Doppler spread bandwidth. The Doppler spread is limited by the 10 msec sampling to approximately 10 Hz. Each tap can be individually Doppler shifted by ± 1000 Hz, however, since the shift is implemented after the interpolation and upsampling to 100 kHz.

The Gaussian values are generated by table lookup from a table of the Gaussian distribution function with 4096 entries. Since these samples are filtered in a floating point processor, and later interpolated, the dynamic range of the fading is very large and only limited by the 16 bit fixed point representation used in the hardware.

5.4 FREQUENCY HOP CONTROL

The hardware interface to the S250C simulator includes frequency-hop decoding modules for several standard frequency hopping radios, tracking the radio's frequency hopping at the simulator's input and output. A hop controller module receives a signal from the radio or modem which tells the simulator to hop to a new frequency as well as which frequency to hop to. When running the simulator at RF, an input frequency synthesizer is hopped synchronously with the radio. At the same time, suitably delayed signals are generated to hop the output frequency synthesizer and channel simulator tap weights. When operating the simulator at baseband, only the channel simulator tap weights are hopped synchronously.

While the hop controller specifies exactly when the transmitter changes frequency, there is no information about when the receiver changes frequency. For this reason the user can, at the start of a simulation, optionally enter the delay of the assumed receiver hopping times. To simplify normal operation the simulator can be instructed to assume the receiver hop time synchronized with the strongest received path, or the with the arithmetic mean delay of the channel.

The synchronization of the hop timing is critical because the S250C uses a single synthesizer for up-conversion. As long as this synthesizer hops when the receiver hops the simulation will be very accurate, even though an earlier or a later path at a different frequency would still be received in reality. The simulator should therefore not be used for collection of bit error statistics until receiver hop timing has stabilized, and the user should check that the hop delay used in the simulator is accurate. More details on this can be found in the software and hardware manuals. Some of the inconvenience of this delay synchronization could be avoided by modifying the simulator with an additional synthesizer and up-converter, allowing some drift of the receiver timing.

5.5 FREQUENCY HOP CORRELATION

The S250C simulator can hop over 128 specified frequencies. At each frequency the delay, power, Doppler spread, and Doppler shift of a path may be different, particularly at HF where the ionospheric propagation can be very different at different frequencies. When hopping to a frequency far away we may assume that the fading tap weights will be independent of the current fading tap weights.

However, when hopping over a small frequency span the fading on any given tap will be correlated, with a correlation coefficient determined by the actual micropath structure in the ionosphere. Therefore we model path weights at different frequencies as correlated complex Gaussian values with a correlation coefficient given by

$$\rho(f_1, f_2) = e^{-|f_1 - f_2|/B_{corr}}$$

where B_{corr} is the correlation bandwidth. For HF this is predicted by the HFPRED prediction program.

If the radios hop back to same frequency within a short time, it is also important that the amplitude and phase of the fading on each path is correctly correlated with the previous complex path weights. For this reason the S250C simulator actually continuously generates tap weights for the maximum of 128 frequencies used in the simulation. However, the simulator assumes that a particular hop band is not revisited until the signal energy from any previous visit dissipates, i.e. the hop period should be larger than the delay spread.

5.6 ADDITIVE GAUSSIAN NOISE

Complex Gaussian noise samples are generated in the DSP with independent, zero-mean real and imaginary components. This is accomplished by generating a pair of uniformly distributed random numbers which provide indices to a table of 4096 values. The table lookup converts uniform random indexing into a sequence of independent, zero-mean numbers having a Gaussian density with tails extending out to $\pm 3.6\sigma$. With a non-fading channel this means that bit error rates below 0.001 will not be accurate and the simulation can give optimistic results. However, with a fading channel the impact of the truncated tails is negligible since most errors are caused by deep fades rather than high noise spikes.

In dual-diversity operation the Gaussian noise samples in receiver 1 are independent of the Gaussian noise samples in receiver 2. When frequency hopping the noise is scaled depending on the frequency.

5.7 IMPULSE NOISE

The user can specify the pulse duration, average period, and maximum strength (impulse power) of the impulse in dB relative to the peak output of the simulator.

The impulse period can be random or periodic. Periodic impulse noise is formed by adding the impulse waveform to the output at the specified rate. This rate is limited by the pulse duration since pulses can not overlap.

Random impulse noise is different in that the rate of occurrence of impulses is instead a random variable whose mean is equal to the specified average pulse rate. Random impulse noise is implemented in the following way:

1. A threshold depending on the average pulse rate is computed at the beginning of the simulation.
2. When a previous pulse has terminated, a random number is generated for each new data sample.
3. If the random number exceeds the threshold, a new impulse is started; if not, no new impulse is started.

The user can specify the duration of the impulse in microseconds. The duration of the impulse must be greater than 10 μ s (a one sample impulse) but should not exceed roughly 1 second. When the pulse is larger than one sample each sample is modulated by a random sign bit, in effect keeping the bandwidth of the pulse constant, spread over the 80 kHz simulation band.

When frequency hopping, the same impulse train is added to the output, independent of the hop frequency.

5.8 JAMMING SIMULATION

In addition to additive noise several other types of jamming can be simulated. Unlike impulse noise, the jamming can be specified independently for each hop frequency. The jammer power level is the same at all the specified jammed frequencies. However, the ratio of jammer to signal power and jammer to background noise power can be varied by specifying different signal and noise levels in each band.

In all cases, the jammer waveform is modeled in the upper sideband and duplicated in the lower sideband. This means that the spectrum of the specified jammer waveform must be in the range [0, 40 kHz] for RF simulation and [300 Hz, 20 kHz] for base band simulation.

Each jammer wave form can be fading, using a specified tap from simulator tapped delay line, or non-fading in which case all six taps are available for the HF signal propagation modeling. When it is specified as non-fading, the same jammer signal appears at the output of both diversities. When the jammer is fading the two diversities can use different taps and thus fade independently.

We now briefly describe the jammer waveform options:

5.8.1 Noise Jamming

Noise-like jamming can be simulated with the built-in additive Gaussian noise described in Section 5.7. There is no special menus in GENPAR for this case, it is assumed the user does this by specifying the appropriate signal and noise levels for each frequency.

5.8.2 Tone Jamming

One or two tones can be simulated, i.e.,

$$a_1 e^{j2\pi f_1 t} + a_2 e^{j2\pi f_2 t}$$

where

a_1 and a_2 are the tone amplitudes, and

f_1 and f_2 are the tone frequencies.

If either a_1 or a_2 are less than or equal to -100 dBm, then that tone is ignored.

5.8.3 Swept FM Jamming

Swept FM is simulated as a linear ramp in frequency, i.e.,

$$a_1 \cdot e^{j2\pi \left[f_1 + (f_2 - f_1) \frac{t'}{2T_p} \right]}$$

where

a_1 is the jammer amplitude,
 f_1 and f_2 are the minimum and maximum jamming frequencies,
 T_p is the sweep period, and
 t' is the time modulo the sweep period.

5.8.4 Sinusoidal FM Jamming

Sinusoidal FM is simulated as a sinusoidal frequency modulation around a center frequency, i.e.,

$$a_1 \cdot e^{j(2\pi f_c t + \beta \sin 2\pi f_m t)}$$

where

a_1 is the jammer amplitude
 f_c is the jammer center frequency
 f_m is the jammer modulation frequency, and
 β is the modulation index.

The instantaneous frequency is then in the range $[f_c - \beta f_m, f_c + \beta f_m]$, which must be in the upper sideband. GENPAR does not always warn the user if this condition is not met.

5.9 INTERMODULATION SIMULATION

The simulator includes the capability of simulating unwanted RF intermodulation products. These products are modeled by a non-fading sinusoidal modulated FM signal as described in Section 2.5.4.3.7, but is at all frequencies and non-fading.

APPENDIX A

HFPRED INPUT/OUTPUT EXAMPLES

A.1 OVERVIEW

This appendix includes three main printouts:

- a) Input data file (.INP) example (section A.2),
- b) Full output file (.OUT) summarizing ionospheric parameter predictions (section A.3). This file is omitted when a short output file is specified,
- c) Parameter output file (.PAR) for processing by GENPAR or HF sim (section A.4).

The output file in section A.3 summarizes the input data, and gives ionospheric predictions followed by HF channel predictions.

The summary of the input data is self-explanatory. The ionospheric parameter predictions section of section A.3 gives the critical frequencies of the E, F1 and F2 layers in MHz, the heights of the bottom, peak and top of each layer in kilometers, the geomagnetic latitude of the mid-latitude trough, the equatorward and poleward latitude boundaries of the auroral zone, local time at dawn and sunset for the specified latitude, month and sunspot number and many other parameters. Some or all of these parameters (depending on the latitude at mid-path) are used by the program to predict the multipath characteristics.

The multipath predictions are listed next in section A.3 as a function of path length (distance) and operating frequency. For each value of path length, the output lists the highest frequency (in MHz) at which reflections from the E-layer, F1-layer and F2-layer (MUF-E, MUF-F1, MUF-F2, respectively) can be observed assuming 1-hop, 2-hop and 3-hop propagation. The output file lists as a function of frequency the various propagation modes, i.e., E, F1, F2-layer reflections or groundwave (GW), the number of hops (reflection from the ionosphere) and whether the mode is an ordinary (0) or extraordinary (X) wave. For each mode type, the output lists the elevation take-off angle (or angle of arrival) in degrees, the total median path loss in dB, made up of the spreading loss (FS-loss), median absorption loss (A-loss), polarization mismatch loss (P-loss), and other miscellaneous losses which are not listed. The output also lists the median signal strength (RSL) of each mode in dBm, delay relative to D/c where D is the path length and c is the speed of light,

Doppler shift in Hz, Doppler smear in Hz, delay smear in μ sec and spatial coherence distance in kilometers.

Following the various mode parameters, the output lists the mean coherence (or correlation) distance of the sum of all modes, the mean relative delay and the rms delay spread in μ sec. The median atmospheric noise and median man-made noise levels, in a bandwidth equal to the data rate and their sum are listed next in dBm.

If the user is interested in other than median values of path loss and atmosphere and man-made noise, the user can obtain correction factors from References c), d) and e) of Section 4.2.

A.2 EQU.INP - Contents of Sample HFPRED Input File

1 0 = input path length, 1 = input link coordinates (IC)
110.,33. Longitude West and latitude at transmit site (IC = 1)
77,-12 Longitude West and latitude at receive site (IC = 1)
40.,50. Longitude and latitude at midpath (IC = 0)
500 Path length (km) (IC = 0)
2.,10.,0.5 Minimum, maximum, and increment in frequency (MHz)
1.,1.,1. Local time at receiver site (decimal hours)
1 Month
20 Sunspot number
2 Magnetic index
2 0 = HFMUFES, 1 = GEORGE-BRADLEY, 2=IONCAP path loss model
0 0 = default cont. U.S., 1 = user input atmos. noise figure
55. Atmospheric noise figure at 1 MHz
0 Propagation direction: 0 = North-South, 1 = East-West
1000. Effective radiated power (Watts)
0 Tx Polarization: 0 = vertical, 1 = horizontal
0 Rx Polarization: 0 = vertical, 1 = horizontal
1 Tx elev. patt.: 0 = omni, 1 = vert monopole, 2 = horiz dipole
1 Rx elev. patt.: 0 = omni, 1 = vert monopole, 2 = horiz dipole
300.,3000. Data rate (bits/sec), receiver bandwidth (Hz)
1 Receiver location: 1 = rural, 2 = suburban, 3 = urban
10 Ground dielectric constant
.01 Conductivity (mho/m)
0 1 = groundwave calculation, 0 = no groundwave calculation

**A.3 EQU.OUT - Contents of HFPRED Propagation Output File
Corresponding to Input File EQU.INP**

HF PROPAGATION PREDICTION
VERSION H1.3
COPYRIGHT 1993-1996
SIGNATRON TECHNOLOGY CORP.

<<< HF PROPAGATION INPUT SUMMARY >>>

MAN-MADE NOISE ENVIRONMENT: RURAL
RCV SITE LOCAL INITIAL TIME(Hrs)= 1.0
DAY AND MONTH=(15, 1)
SUNSPOT NUMBER= 20
MAG. INDEX= 2

EFFECTIVE RADIATED POWER = 1000. Watts

TRANSMIT ANTENNA CHARACTERISTICS:

POLARIZATION: VERTICAL
ELEVATION PATTERN: VERTICAL MONPOLE
RECEIVE ANTENNA CHARACTERISTICS:
POLARIZATION: VERTICAL
ELEVATION PATTERN: VERTICAL MONPOLE

GROUND DIELECTRIC CONSTANT= 10.0
GROUND CONDUCTIVITY= 1.000E-02 mhos/meter

DATA RATE = 300.0 bps
CHANNEL SYMBOL RATE = 3000.0 Hz

UP TO 6 STRONGEST RAYS LISTED IN ORDER OF ARRIVAL

IONCAP PATH LOSS MODEL USED

SIGNATRON TECHNOLOGY

<<< HF MULTIPATH & SYSTEM PERFORMANCE >>>

====> TX LONGITUDE WEST (deg) = 110.0

HF LINK COORDINATES:

TRANSMIT SITE:

LONGITUDE(DEG)=110.0 LATITUDE(DEG)= 33.0

RECEIVE SITE:

LONGITUDE(DEG)= 77.0 LATITUDE(DEG)=-12.0

MID-PATH COORDINATES:

LONGITUDE (DEG) = 92.2

LATITUDE (DEG) = 10.9

<<<< SUMMARY OF IONOSPHERIC PARAMETERS >>>>

MONTH,SSN,KP,Q: 1 20 2 2
 LONGITUDE AND LATITUDE: 92.1973 10.9375
 GEOMAGNETIC LONG. AND LAT.: 108.717 21.6418
 MAG.DIP LAT. AND MODIF.DIP LAT: 38.4336 34.0968
 LOCAL AND GEOMAGNETIC MID-PATH TIME: 23.8535 23.8447
 DAWN AND SUNSET: 5.51512 19.1227
 CRITICAL FREQUENCIES F0E,F0F1,F0F2:
 0.583441 0.100000 3.28407
 LAYER MAXIMA HEIGHTS HE,HF1,HF2:
 135.000 200.000 330.482
 LAYER SEMI-THICKNESS: BE,BF1,BF2
 20.0000 40.0000 80.2163
 TROUGH BOUNDARIES: YTS,YTN
 55.7042 60.7042
 AURORAL OVAL BOUNDARIES: YAS,YAN
 65.0042 71.4042
 FLIZ BOUNDARIES: YFLS,YFLN
 65.6542 69.8525
 POLAR LAYER CRITICAL FREQUENCIES:F0EA,F0F2P
 0.000000 4.04374
 AURORAL E & F2 LAYER HEIGHTS: HEA,HF2P
 135.000 470.000
 AURORAL E & F2 LAYER SEMI-THICKNESS: BEA,BF2P
 0.000000 150.000
 CRITICAL FREQUENCIES F0E,F0F1,F0F2
 0.583441 0.100000 3.28407
 E-LAYER HEIGHTS H0,HE,H1
 115.000 135.000 155.000
 F1-LAYER HEIGHTS HF1,HF2,H2:
 160.000 200.000 240.000
 F2-LAYER HEIGHTS HF2,HF2:
 250.265 330.482
 LAYER SEMI-THICKNESS: BE,BF1,BF2
 20.0000 40.0000 80.2163
 RMS FLUCTUATION & OUTER SCALE DN,DN2,XLC:
 0.152682 0.114168 1.50000
 IRREG. DRIFT VELOCITY V: 0.265843E-01
 GYRO FREQUENCIES FHD,FHE,FHF1,FHF2,FL:
 0.992105 0.969403 0.940914 0.887009 0.616699
 ABSORPTION INDICES LFAND,ADEV,ANDEV:
 3.13215 42.0683 31.6850

 LOCAL TIME, TX = 23.0
 MID-PATH TIME = 23.9
 UNIVERSAL TIME = 6.0

 =====> GREAT CIRCLE DISTANCE (km) = 6106.7

 MAXIMUM USABLE FREQUENCY = 7.68 MHz
 LONG (deg) = 110.0 TIME (hr) = 1.0 DIST (km) = 6106.7 FREQ (MHz) = 2.00

SIGNATRON TECHNOLOGY

MODE	No.HOPS	O-X	ANGLE (deg)	LOSS (dB)	FS-LOSS (dB)	A-LOSS (dB)	P-LOSS (dB)	ANT-GAIN (dB)
------	---------	-----	----------------	--------------	-----------------	----------------	----------------	------------------

F2	3	X	10.27	144.91	115.67	23.62	1.00	4.80
F2	3	O	10.28	138.48	115.66	16.89	1.00	4.80
F2	4	X	15.50	149.84	115.25	27.53	1.00	6.57
F2	4	O	15.52	142.22	115.24	19.68	1.00	6.58
F2	5	X	20.22	153.69	115.24	30.17	1.00	7.15
F2	5	O	20.26	145.22	115.23	21.56	1.00	7.15

MODE	No.HOPS	O-X	RSL (dBm)	DELAY (us)	DOP.SHIFT (Hz)	DOP.SMEAR (Hz)	DEL.SMEAR (us)	CORR (km)
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F2	3	X	-80.12	1136.44	-0.015	0.061	1.76	0.280
F2	3	O	-73.68	1137.53	-0.015	0.061	1.76	0.279
F2	4	X	-83.27	1602.67	-0.024	0.063	1.40	0.269
F2	4	O	-75.65	1605.62	-0.024	0.063	1.40	0.267
F2	5	X	-86.55	2202.58	-0.034	0.070	1.44	0.240
F2	5	O	-78.07	2209.22	-0.035	0.072	1.46	0.237

RMS CORRELATION DISTANCE (km) = 0.2686E+00

AVERAGE RELATIVE DELAY (usec) = 1469.76

2-SIGMA DELAY SPREAD (usec) = 793.48

ATMOSPHERIC NOISE POWER(dBm) = -69.63

MAN MADE NOISE POWER(dBm) = -104.79

TOTAL NOISE POWER(dBm) = -69.63

PERCENTILE	SKYWAVE RSL dBm	Eb/No dB	BIT ERROR RATE	
			L=1	L=BT
10.0	-64.78	4.85	1.233E-01	6.503E-02
50.0	-69.90	-0.27	2.578E-01	2.241E-01
90.0	-81.42	-11.79	4.689E-01	4.684E-01

LONG (deg) = 110.0 TIME (hr) = 1.0 DIST (km) = 6106.7 FREQ (MHz) = 2.50

MODE	No.HOPS	O-X	ANGLE (deg)	LOSS (dB)	FS-LOSS (dB)	A-LOSS (dB)	P-LOSS (dB)	ANT-GAIN (dB)
------	---------	-----	----------------	--------------	-----------------	----------------	----------------	------------------

F2	3	X	9.74	144.20	116.82	21.42	1.00	3.73
F2	3	O	9.76	137.95	116.81	14.89	1.00	3.74
F2	4	X	15.24	149.07	116.83	24.58	1.00	5.96
F2	4	O	15.27	141.77	116.82	17.08	1.00	5.97
F2	5	X	20.16	152.72	116.94	26.71	1.00	6.69
F2	5	O	20.21	144.67	116.92	18.54	1.00	6.70

SIGNATRON TECHNOLOGY

MODE	No.HOPS	O-X	RSL (dBm)	DELAY (us)	DOP.SHIFT (Hz)	DOP.SMEAR (Hz)	DEL.SMEAR (us)	CORR (km)
F2	3	X	-80.48	1068.18	-0.019	0.048	0.79	0.355
F2	3	O	-74.21	1070.08	-0.019	0.048	0.79	0.352
F2	4	X	-83.11	1562.41	-0.030	0.059	0.94	0.289
F2	4	O	-75.81	1567.35	-0.031	0.060	0.96	0.283
F2	5	X	-86.03	2190.19	-0.045	0.078	1.25	0.217
F2	5	O	-77.97	2201.40	-0.046	0.081	1.30	0.209

rms CORRELATION DISTANCE (km)= 0.3078E+00

AVERAGE RELATIVE DELAY (usec)= 1446.27

2-SIGMA DELAY SPREAD (usec)= 853.55

ATMOSPHERIC NOISE POWER(dBm)= -72.89

MAN MADE NOISE POWER(dBm)= -108.11

TOTAL NOISE POWER(dBm)= -72.89

PERCENTILE	SKYWAVE RSL dBm	Eb/No dB	BIT ERROR RATE	
			L=1	L=BT
10.0	-65.04	7.85	7.049E-02	1.965E-02
50.0	-70.16	2.73	1.740E-01	1.200E-01
90.0	-81.68	-8.79	4.417E-01	4.395E-01

LONG (deg) = 110.0 TIME (hr) = 1.0 DIST (km) = 6106.7 FREQ (MHz) = 3.00

MODE	No.HOPS	O-X	ANGLE (deg)	LOSS (dB)	FS-LOSS (dB)	A-LOSS (dB)	P-LOSS (dB)	ANT-GAIN (dB)
F2	3	X	9.63	143.08	118.18	18.70	1.00	2.97
F2	3	O	9.65	137.46	118.16	12.85	1.00	2.99
F2	4	X	15.26	147.72	118.24	21.32	1.00	5.47
F2	4	O	15.31	141.20	118.22	14.63	1.00	5.48
F2	5	X	20.33	151.19	118.37	23.05	1.00	6.31
F2	5	O	20.42	144.02	118.34	15.80	1.00	6.31

MODE	No.HOPS	O-X	RSL (dBm)	DELAY (us)	DOP.SHIFT (Hz)	DOP.SMEAR (Hz)	DEL.SMEAR (us)	CORR (km)
F2	3	X	-80.11	1053.82	-0.023	0.047	0.63	0.358
F2	3	O	-74.47	1056.71	-0.024	0.048	0.64	0.352
F2	4	X	-82.25	1565.17	-0.038	0.068	0.91	0.249
F2	4	O	-75.72	1572.79	-0.039	0.070	0.94	0.240
F2	5	X	-84.88	2222.38	-0.057	0.103	1.39	0.165
F2	5	O	-77.70	2240.18	-0.059	0.108	1.46	0.157

SIGNATRON TECHNOLOGY

rms CORRELATION DISTANCE (km)= 0.2867E+00
 AVERAGE RELATIVE DELAY (usec)= 1470.12
 2-SIGMA DELAY SPREAD (usec)= 902.27

ATMOSPHERIC NOISE POWER(dBm)= -75.62
 MAN MADE NOISE POWER(dBm)= -110.83
 TOTAL NOISE POWER(dBm)= -75.61

PERCENTILE	SKYWAVE RSL	Eb/No	BIT ERROR RATE	
			L=1	L=BT
10.0	-64.95	10.67	3.951E-02	4.731E-03
50.0	-70.07	5.55	1.090E-01	4.943E-02
90.0	-81.59	-5.97	3.991E-01	3.926E-01

LONG (deg) = 110.0 TIME (hr) = 1.0 DIST (km) = 6106.7 FREQ (MHz) = 3.50

MODE	No.HOPS	O-X	ANGLE (deg)	LOSS (dB)	FS-LOSS (dB)	A-LOSS (dB)	P-LOSS (dB)	ANT-GAIN (dB)
------	---------	-----	-------------	-----------	--------------	-------------	-------------	---------------

F2	3	X	9.65	141.85	119.38	16.08	1.00	2.38
F2	3	O	9.69	137.01	119.36	11.04	1.00	2.40
F2	4	X	15.40	146.27	119.44	18.24	1.00	5.06
F2	4	O	15.48	140.68	119.42	12.50	1.00	5.08
F2	5	X	20.65	149.61	119.56	19.61	1.00	5.97
F2	5	O	20.79	143.45	119.51	13.41	1.00	5.99

MODE	No.HOPS	O-X	RSL (dBm)	DELAY (us)	DOP.SHIFT (Hz)	DOP.SMEAR (Hz)	DEL.SMEAR (us)	CORR (km)
------	---------	-----	-----------	------------	----------------	----------------	----------------	-----------

F2	3	X	-79.47	1056.52	-0.028	0.054	0.62	0.312
F2	3	O	-74.60	1060.69	-0.029	0.056	0.64	0.303
F2	4	X	-81.22	1588.06	-0.047	0.087	1.01	0.194
F2	4	O	-75.60	1599.40	-0.048	0.091	1.05	0.186
F2	5	X	-83.63	2284.16	-0.073	0.140	1.64	0.121
F2	5	O	-77.47	2311.76	-0.076	0.149	1.75	0.114

rms CORRELATION DISTANCE (km)= 0.2374E+00
 AVERAGE RELATIVE DELAY (usec)= 1510.83
 2-SIGMA DELAY SPREAD (usec)= 958.02

ATMOSPHERIC NOISE POWER(dBm)= -78.02
 MAN MADE NOISE POWER(dBm)= -113.13
 TOTAL NOISE POWER(dBm)= -78.02

PERCENTILE	SKYWAVE RSL	Eb/No	BIT ERROR RATE	
			L=1	L=BT
10.0	-64.74	13.28	2.244E-02	1.039E-03
50.0	-69.86	8.16	6.625E-02	1.644E-02
90.0	-81.38	-3.36	3.422E-01	3.262E-01

LONG (deg) = 110.0 TIME (hr) = 1.0 DIST (km) = 6106.7 FREQ (MHz) = 4.00

SIGNATRON TECHNOLOGY

MODE	No.HOPS	O-X	ANGLE (deg)	LOSS (dB)	FS-LOSS (dB)	A-LOSS (dB)	P-LOSS (dB)	ANT-GAIN (dB)
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F2	3	X	9.75	140.73	120.43	13.73	1.00	1.91
F2	3	O	9.79	136.65	120.41	9.48	1.00	1.94
F2	4	X	15.65	144.99	120.46	15.49	1.00	4.72
F2	4	O	15.75	140.28	120.42	10.68	1.00	4.75
F2	5	X	21.12	148.25	120.53	16.55	1.00	5.69
F2	5	O	21.33	143.06	120.46	11.37	1.00	5.71

MODE	No.HOPS	O-X	RSL (dBm)	DELAY (us)	DOP.SHIFT (Hz)	DOP.SMEAR (Hz)	DEL.SMEAR (us)	CORR (km)
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F2	3	X	-78.82	1068.61	-0.034	0.067	0.67	0.254
F2	3	O	-74.71	1074.46	-0.035	0.069	0.70	0.245
F2	4	X	-80.27	1626.40	-0.058	0.115	1.16	0.148
F2	4	O	-75.53	1643.03	-0.060	0.120	1.23	0.140
F2	5	X	-82.56	2376.46	-0.092	0.192	1.98	0.088
F2	5	O	-77.35	2419.50	-0.098	0.206	2.13	0.082

RMS CORRELATION DISTANCE (km)= 0.1871E+00

AVERAGE RELATIVE DELAY (usec)= 1564.25

2-SIGMA DELAY SPREAD (usec)= 1029.21

ATMOSPHERIC NOISE POWER(dBm)= -80.21

MAN MADE NOISE POWER(dBm)= -115.11

TOTAL NOISE POWER(dBm)= -80.21

PERCENTILE	SKYWAVE RSL dBm	Eb/No dB	BIT ERROR RATE	
			L=1	L=BT
10.0	-64.53	15.68	1.318E-02	2.327E-04
50.0	-69.65	10.56	4.043E-02	4.873E-03
90.0	-81.17	-0.96	2.776E-01	2.470E-01

LONG (deg) = 110.0 TIME (hr) = 1.0 DIST (km) = 6106.7 FREQ (MHz) = 4.50

MODE	No.HOPS	O-X	ANGLE (deg)	LOSS (dB)	FS-LOSS (dB)	A-LOSS (dB)	P-LOSS (dB)	ANT-GAIN (dB)
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F2	3	X	9.90	139.81	121.34	11.71	1.00	1.53
F2	3	O	9.96	136.42	121.30	8.17	1.00	1.58
F2	4	X	15.99	143.97	121.32	13.12	1.00	4.45
F2	4	O	16.14	140.03	121.25	9.13	1.00	4.49
F2	5	X	21.78	147.23	121.30	13.90	1.00	5.46
F2	5	O	22.12	142.85	121.17	9.62	1.00	5.48

SIGNATRON TECHNOLOGY

MODE	No.HOPS	O-X	RSL (dBm)	DELAY (us)	DOP.SHIFT (Hz)	DOP.SMEAR (Hz)	DEL.SMEAR (us)	CORR (km)
F2	3	X	-78.28	1088.02	-0.041	0.084	0.75	0.201
F2	3	O	-74.84	1096.12	-0.042	0.088	0.79	0.193
F2	4	X	-79.52	1680.90	-0.071	0.151	1.37	0.112
F2	4	O	-75.54	1705.36	-0.075	0.160	1.45	0.106
F2	5	X	-81.78	2509.95	-0.118	0.264	2.41	0.064
F2	5	O	-77.37	2580.10	-0.128	0.287	2.63	0.059

rms CORRELATION DISTANCE (km)= 0.1457E+00

AVERAGE RELATIVE DELAY (usec)= 1641.52

2-SIGMA DELAY SPREAD (usec)= 1239.56

ATMOSPHERIC NOISE POWER(dBm)= -82.26

MAN MADE NOISE POWER(dBm)= -116.87

TOTAL NOISE POWER(dBm)= -82.25

PERCENTILE	SKYWAVE RSL dBm	Eb/No dB	BIT ERROR RATE	
			L=1	L=BT
10.0	-64.39	17.86	8.049E-03	5.646E-05
50.0	-69.51	12.74	2.525E-02	1.410E-03
90.0	-81.03	1.22	2.151E-01	1.686E-01

LONG (deg) = 110.0 TIME (hr) = 1.0 DIST (km) = 6106.7 FREQ (MHz) = 5.00

MODE	No.HOPS	O-X	ANGLE (deg)	LOSS (dB)	FS-LOSS (dB)	A-LOSS (dB)	P-LOSS (dB)	ANT-GAIN (dB)
F2	3	X	10.10	139.12	122.12	9.99	1.00	1.25
F2	3	O	10.19	136.30	122.08	7.06	1.00	1.31
F2	4	X	16.45	143.25	122.01	11.10	1.00	4.24
F2	4	O	16.67	139.95	121.90	7.80	1.00	4.30
F2	5	X	22.74	146.57	121.79	11.61	1.00	5.27
F2	5	O	23.33	142.73	121.49	8.08	1.00	5.31

MODE	No.HOPS	O-X	RSL (dBm)	DELAY (us)	DOP.SHIFT (Hz)	DOP.SMEAR (Hz)	DEL.SMEAR (us)	CORR (km)
F2	3	X	-77.88	1114.68	-0.049	0.106	0.86	0.159
F2	3	O	-74.99	1125.86	-0.051	0.111	0.90	0.152
F2	4	X	-79.01	1756.13	-0.088	0.198	1.62	0.085
F2	4	O	-75.64	1793.17	-0.094	0.212	1.74	0.080
F2	5	X	-81.30	2713.46	-0.156	0.367	3.00	0.046
F2	5	O	-77.42	2843.62	-0.177	0.412	3.36	0.041

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rms CORRELATION DISTANCE (km)= 0.1123E+00
 AVERAGE RELATIVE DELAY (usec)= 1831.96
 2-SIGMA DELAY SPREAD (usec)= 1891.42

ATMOSPHERIC NOISE POWER(dBm)= -84.19
 MAN MADE NOISE POWER(dBm)= -118.44
 TOTAL NOISE POWER(dBm)= -84.19

PERCENTILE	SKYWAVE RSL	Eb/No	BIT ERROR RATE	
			L=1	L=BT
10.0	-64.25	19.94	5.014E-03	1.494E-05
50.0	-69.37	14.82	1.594E-02	4.166E-04
90.0	-80.89	3.30	1.592E-01	1.036E-01

LONG (deg) = 110.0 TIME (hr) = 1.0 DIST (km) = 6106.7 FREQ (MHz) = 5.50

MODE	No.HOPS	O-X	ANGLE (deg)	LOSS (dB)	FS-LOSS (dB)	A-LOSS (dB)	P-LOSS (dB)	ANT-GAIN (dB)
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F2	3	X	10.37	138.67	122.79	8.54	1.00	1.05
F2	3	O	10.49	136.31	122.72	6.11	1.00	1.13
F2	4	X	17.08	142.82	122.50	9.38	1.00	4.11
F2	4	O	17.42	139.97	122.30	6.66	1.00	4.20
F2	5	O	26.37	139.71	118.65	6.48	1.00	5.18
F2	5	O	29.12	141.59	121.22	6.03	1.00	5.14

MODE	No.HOPS	O-X	RSL (dBm)	DELAY (us)	DOP.SHIFT (Hz)	DOP.SMEAR (Hz)	DEL.SMEAR (us)	CORR (km)
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F2	3	X	-77.62	1149.74	-0.058	0.134	0.99	0.126
F2	3	O	-75.18	1165.34	-0.061	0.141	1.04	0.120
F2	4	X	-78.71	1862.96	-0.111	0.263	1.95	0.064
F2	4	O	-75.78	1923.38	-0.122	0.287	2.12	0.059
F2	5	O	-74.53	3573.84	-0.307	0.720	8.25	0.023
F2	5	O	-76.46	4339.61	-0.437	0.997	39.86	0.017

rms CORRELATION DISTANCE (km)= 0.7506E-01
 AVERAGE RELATIVE DELAY (usec)= 2566.66
 2-SIGMA DELAY SPREAD (usec)= 2542.26

ATMOSPHERIC NOISE POWER(dBm)= -86.05
 MAN MADE NOISE POWER(dBm)= -119.86
 TOTAL NOISE POWER(dBm)= -86.05

PERCENTILE	SKYWAVE RSL	Eb/No	BIT ERROR RATE	
			L=1	L=BT
10.0	-62.87	23.18	2.391E-03	1.030E-07
50.0	-67.99	18.06	7.691E-03	9.471E-06
90.0	-79.51	6.54	9.073E-02	3.039E-02

LONG (deg) = 110.0 TIME (hr) = 1.0 DIST (km) = 6106.7 FREQ (MHz) = 6.00

SIGNATRON TECHNOLOGY

MODE	No.HOPS	O-X	ANGLE (deg)	LOSS (dB)	FS-LOSS (dB)	A-LOSS (dB)	P-LOSS (dB)	ANT-GAIN (dB)
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F2	3	X	10.71	138.43	123.33	7.32	1.00	0.93
F2	3	O	10.88	136.44	123.23	5.30	1.00	1.05
F2	4	X	18.03	142.56	122.64	7.88	1.00	4.07
F2	4	O	18.69	139.75	122.06	5.61	1.00	4.21
F2	4	O	25.73	145.80	129.75	4.49	1.00	4.96
F2	4	X	27.46	150.80	133.47	5.88	1.00	4.97

MODE	No.HOPS	O-X	RSL (dBm)	DELAY (us)	DOP.SHIFT (Hz)	DOP.SMEAR (Hz)	DEL.SMEAR (us)	CORR (km)
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F2	3	X	-77.50	1195.87	-0.070	0.169	1.14	0.100
F2	3	O	-75.39	1218.27	-0.075	0.179	1.21	0.094
F2	4	X	-78.49	2030.72	-0.147	0.359	2.42	0.047
F2	4	O	-75.54	2153.02	-0.170	0.409	2.73	0.041
F2	4	O	-80.84	3746.22	-0.474	1.058	45.21	0.016
F2	4	X	-85.82	4234.56	-0.557	1.257	92.71	0.013

ITMS CORRELATION DISTANCE (km)= 0.7157E-01

AVERAGE RELATIVE DELAY (usec)= 1907.35

2-SIGMA DELAY SPREAD (usec)= 1691.89

ATMOSPHERIC NOISE POWER(dBm)= -87.85

MAN MADE NOISE POWER(dBm)= -121.15

TOTAL NOISE POWER(dBm)= -87.84

PERCENTILE	SKYWAVE RSL dBm	Eb/No dB	BIT ERROR RATE	
			L=1	L=BT
10.0	-64.84	23.01	2.489E-03	5.934E-07
50.0	-69.96	17.89	8.001E-03	4.088E-05
90.0	-81.48	6.37	9.375E-02	3.940E-02

LONG (deg) = 110.0 TIME (hr) = 1.0 DIST (km) = 6106.7 FREQ (MHz) = 6.50

MODE	No.HOPS	O-X	ANGLE (deg)	LOSS (dB)	FS-LOSS (dB)	A-LOSS (dB)	P-LOSS (dB)	ANT-GAIN (dB)
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F2	3	X	11.17	138.39	123.71	6.28	1.00	0.92
F2	3	O	11.41	136.65	123.53	4.59	1.00	1.09
F2	4	X	20.12	140.46	120.53	6.41	1.00	4.24
F2	4	X	23.16	142.82	123.67	5.81	1.00	4.61
F2	3	O	21.09	149.13	137.63	3.20	1.00	4.38
F2	3	X	22.22	152.85	140.43	4.19	1.00	4.52

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MODE	No.HOPS	O-X	RSL (dBm)	DELAY (us)	DOP.SHIFT (Hz)	DOP.SMEAR (Hz)	DEL.SMEAR (us)	CORR (km)
F2	3	X	-77.47	1258.57	-0.086	0.215	1.34	0.079
F2	3	O	-75.56	1292.88	-0.093	0.231	1.44	0.073
F2	4	X	-76.22	2431.55	-0.229	0.567	3.99	0.030
F2	4	X	-78.20	3098.42	-0.358	0.859	21.78	0.020
F2	3	O	-84.75	3107.21	-0.485	1.060	127.55	0.016
F2	3	X	-88.33	3385.06	-0.534	1.187	251.59	0.014

rms CORRELATION DISTANCE (km)= 0.5674E-01

AVERAGE RELATIVE DELAY (usec)= 1997.05

2-SIGMA DELAY SPREAD (usec)= 1544.16

ATMOSPHERIC NOISE POWER(dBm)= -89.59

MAN MADE NOISE POWER(dBm)= -122.35

TOTAL NOISE POWER(dBm)= -89.59

PERCENTILE	SKYWAVE RSL dBm	Eb/No dB	BIT ERROR RATE	
			L=1	L=BT
10.0	-65.36	24.23	1.882E-03	8.553E-07
50.0	-70.48	19.11	6.066E-03	2.701E-05
90.0	-82.00	7.59	7.421E-02	2.207E-02

LONG (deg) = 110.0 TIME (hr) = 1.0 DIST (km) = 6106.7 FREQ (MHz) = 7.00

MODE	No.HOPS	O-X	ANGLE (deg)	LOSS (dB)	FS-LOSS (dB)	A-LOSS (dB)	P-LOSS (dB)	ANT-GAIN (dB)
F2	3	X	11.82	138.46	123.82	5.37	1.00	1.05
F2	3	O	12.23	136.72	123.38	3.96	1.00	1.30
F2	3	O	18.41	144.05	131.61	3.12	1.00	3.67
F2	3	X	19.58	147.81	134.56	4.00	1.00	3.92

MODE	No.HOPS	O-X	RSL (dBm)	DELAY (us)	DOP.SHIFT (Hz)	DOP.SMEAR (Hz)	DEL.SMEAR (us)	CORR (km)
F2	3	X	-77.41	1351.08	-0.109	0.279	1.61	0.061
F2	3	O	-75.42	1412.44	-0.123	0.310	1.78	0.055
F2	3	O	-80.37	2509.28	-0.368	0.847	28.33	0.020
F2	3	X	-83.89	2759.63	-0.418	0.971	50.81	0.017

rms CORRELATION DISTANCE (km)= 0.5116E-01

AVERAGE RELATIVE DELAY (usec)= 1652.72

2-SIGMA DELAY SPREAD (usec)= 1000.37

ATMOSPHERIC NOISE POWER(dBm)= -91.30

MAN MADE NOISE POWER(dBm)= -123.45

TOTAL NOISE POWER(dBm)= -91.29

SIGNATRON TECHNOLOGY

PERCENTILE	SKYWAVE RSL dBm	Eb/No dB	BIT ERROR RATE	
			L=1	L=BT
10.0	-67.09	24.21	1.890E-03	3.112E-06
50.0	-72.21	19.09	6.094E-03	8.961E-05
90.0	-83.73	7.57	7.450E-02	3.531E-02

LONG (deg) = 110.0 TIME (hr) = 1.0 DIST (km) = 6106.7 FREQ (MHz) = 7.50

MODE	No.HOPS	O-X	ANGLE (deg)	LOSS (dB)	FS-LOSS (dB)	A-LOSS (dB)	P-LOSS (dB)	ANT-GAIN (dB)
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F2	3	X	12.99	137.86	122.86	4.52	1.00	1.46
F2	3	X	16.84	142.17	127.76	3.89	1.00	3.03

MODE	No.HOPS	O-X	RSL dBm	DELAY (us)	DOP.SHIFT (Hz)	DOP.SMEAR (Hz)	DEL.SMEAR (us)	CORR (km)
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F2	3	X	-76.40	1526.73	-0.152	0.392	2.09	0.043
F2	3	X	-79.14	2193.79	-0.302	0.741	14.28	0.023

rms CORRELATION DISTANCE (km)= 0.3735E-01

AVERAGE RELATIVE DELAY (usec)= 1758.48

2-SIGMA DELAY SPREAD (usec)= 635.25

ATMOSPHERIC NOISE POWER(dBm)= -92.97

MAN MADE NOISE POWER(dBm)= -124.48

TOTAL NOISE POWER(dBm)= -92.96

PERCENTILE	SKYWAVE RSL dBm	Eb/No dB	BIT ERROR RATE	
			L=1	L=BT
10.0	-69.43	23.54	2.204E-03	4.239E-05
50.0	-74.55	18.42	7.094E-03	4.291E-04
90.0	-86.07	6.90	8.479E-02	4.412E-02

FREQUENCY OF 8.00 MHz IS ABOVE THE MUF

FREQUENCY OF 8.50 MHz IS ABOVE THE MUF

FREQUENCY OF 9.00 MHz IS ABOVE THE MUF

FREQUENCY OF 9.50 MHz IS ABOVE THE MUF

FREQUENCY OF 10.00 MHz IS ABOVE THE MUF

A.4 EQU.PAR - GENPAR Compatible Output File Corresponding to Input File EQU.INP

HFPRED version H1.3

2.00000	0.500000	17	0	
60.000000	1 0 0	None		
1 2.00000	-48.3789	-45.3789		
-80.1162	-73.6804	-83.2662	-75.6451	-86.5484
-78.0711				
1136 1137	1602 1605	2202 2209		
-0.152471E-01	-0.153390E-01	-0.236053E-01	-0.238237E-01	-0.342700E-01
-0.347357E-01				
0.605346E-01	0.606494E-01	0.628765E-01	0.633025E-01	0.703622E-01
0.715246E-01				
2 2.50000	-51.6360	-48.6360		
-80.4782	-74.2139	-83.1081	-75.8063	-86.0313
-77.9738				
1068 1070	1562 1567	2190 2201		
-0.190247E-01	-0.191969E-01	-0.302066E-01	-0.306365E-01	-0.447449E-01
-0.456949E-01				
0.477209E-01	0.481227E-01	0.586006E-01	0.597911E-01	0.781275E-01
0.809187E-01				
3 3.00000	-54.3653	-51.3653		
-80.1059	-74.4721	-82.2488	-75.7224	-84.8808
-77.7041				
1053 1056	1565 1572	2222 2240		
-0.234286E-01	-0.237309E-01	-0.378875E-01	-0.386673E-01	-0.572525E-01
-0.590347E-01				
0.472342E-01	0.481238E-01	0.680739E-01	0.703983E-01	0.102596
0.107668				
4 3.50000	-56.7698	-53.7698		
-79.4673	-74.6040	-81.2156	-75.6003	-83.6320
-77.4659				
1056 1060	1588 1599	2284 2311		
-0.284315E-01	-0.289323E-01	-0.468968E-01	-0.482336E-01	-0.725739E-01
-0.757626E-01				
0.542104E-01	0.557607E-01	0.871866E-01	0.910162E-01	0.140354
0.148729				
5 4.00000	-58.9610	-55.9610		
-78.8212	-74.7115	-80.2677	-75.5285	-82.5570
-77.3464				
1068 1074	1626 1643	2376 2419		
-0.341608E-01	-0.349555E-01	-0.576930E-01	-0.599103E-01	-0.920439E-01
-0.976682E-01				
0.667500E-01	0.691341E-01	0.114544	0.120465	0.192340
0.205987				
6 4.50000	-61.0048	-58.0048		
-78.2782	-74.8355	-79.5183	-75.5414	-81.7792
-77.3696				
1088 1096	1680 1705	2509 2580		
-0.408216E-01	-0.420485E-01	-0.710066E-01	-0.746432E-01	-0.118113
-0.128307				
0.840529E-01	0.875217E-01	0.150741	0.159796	0.263548
0.286723				
7 5.00000	-62.9422	-59.9422		

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-77.8759	-74.9907	-79.0059	-75.6428	-81.3048
-77.4193				
1114 1125 1756 1793 2713 2843				
-0.487152E-01 -0.505830E-01 -0.880773E-01 -0.941353E-01 -0.156228				
-0.176932				
0.106176 0.111134 0.198275 0.212479 0.366619				
0.411556				
8 5.50000 -64.7997 -61.7997				
-77.6195 -75.1796 -78.7149 -75.7777 -74.5317				
-76.4585				
1149 1165 1862 1923 3573 4339				
-0.583001E-01 -0.611439E-01 -0.111318 -0.122056 -0.307151				
-0.436985				
0.133918 0.141038 0.262768 0.286799 0.720255				
0.996989				
9 6.00000 -66.5952 -63.5952				
-77.4967 -75.3899 -78.4891 -75.5358 -80.8405				
-85.8230				
1195 1218 2030 2153 3746 4234				
-0.703286E-01 -0.747436E-01 -0.146811 -0.170104 -0.473883				
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-88.3306				
1258 1292 2431 3098 3107 3385				
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-200.000				
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-76.3994 -79.1371 -200.000 -200.000 -200.000				
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14 8.500000 -200.000000 -197.000000				
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15 9.000000 -200.000000 -197.000000				

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